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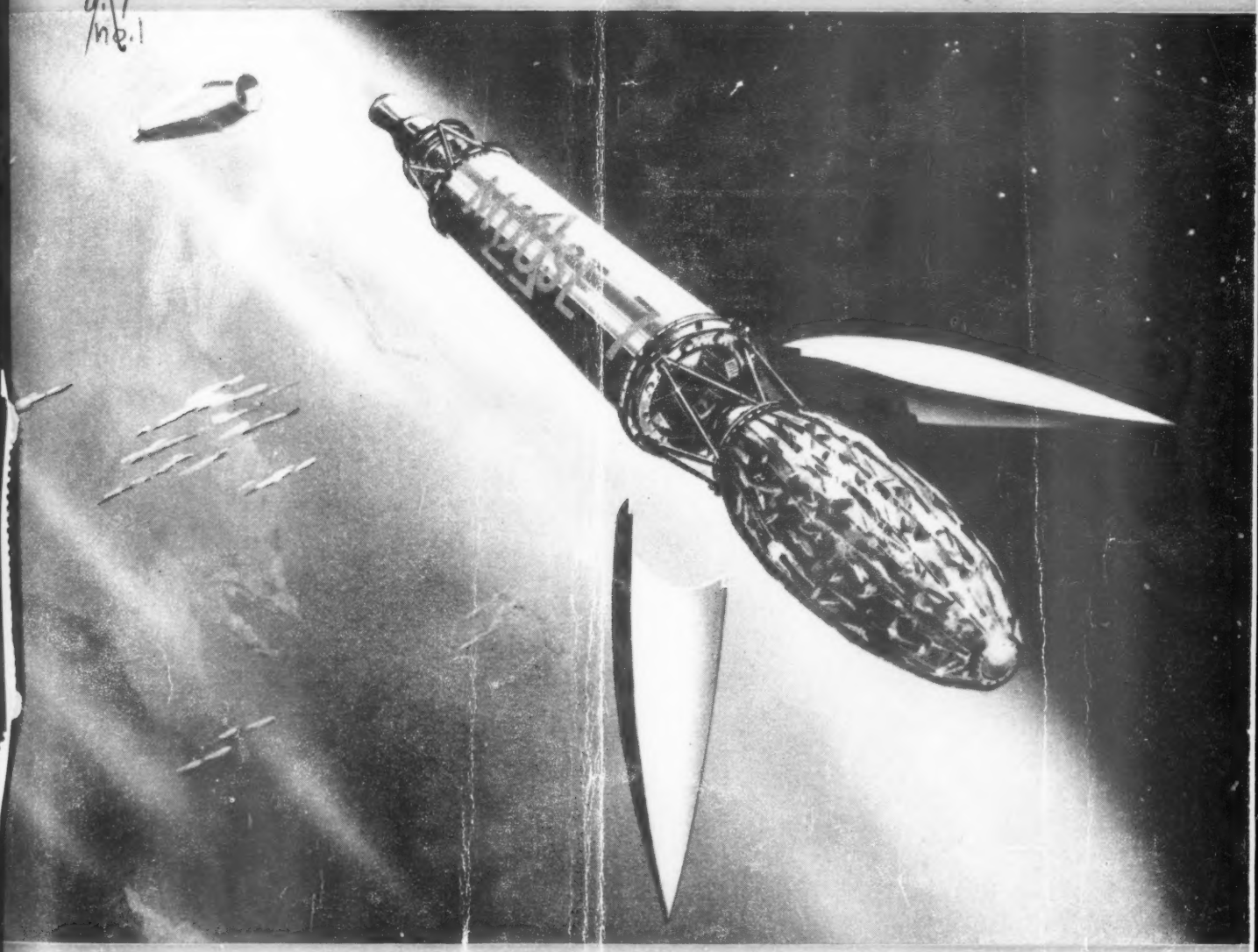

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COVER

An impression by John W. Wood of the Minimum Satellite Vehicle which was the subject of a British design study in 1951. In this picture, the artist has attempted to illustrate four sequences leading to the establishment of the satellite (a large inflatable metal-foil sphere) in the orbit: (*a*) release of the 2nd stage booster; (*b*) jettisoning of the ballistic nosecap; (*c*) acceleration of the 3rd stage to orbital velocity, and (*d*) the inflation of the foil-satellite. In practice, (*d*) would not occur until after the propulsion of stage 3 had ceased.

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The British Interplanetary Society

The British Interplanetary Society was founded in 1933 to promote the development of interplanetary exploration and communication by the study of rocket engineering, astronomy and other associated sciences. It now includes among its members many British and foreign workers prominent in these fields.

The Society organizes meetings, lectures, exhibitions and film shows. These programmes are planned not only to assist the spread of technical knowledge, but to stress the limitless possibilities of rocket propulsion, and in particular the ultimate implications to human society of the crossing of space.

The Journal of the Society is published bi-monthly, and is issued free to members. Full particulars of membership can be obtained from the Secretary. The Secretarial Address is: 12 Bessborough Gardens, London, S.W.1; telephone TATe Gallery 9371.

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Editorial

For many years now, the British Interplanetary Society has issued a bi-monthly *Journal*. Numerous original papers have been published, and there is no doubt that these papers have been of considerable value to research workers.

There have, of course, been criticisms, and broadly speaking the critics have been divided into two camps: those who say that the *Journal* is too technical, and those who say that it is not technical enough. Significantly, these two camps have always been more or less equal numerically.

Since the British Interplanetary Society is making a real contribution to research, there is not room in its *Journal* for all the more popular papers that so many people enjoy reading. On the other hand, the spreading of correct information is one of the Society's chief aims, and this has become even more important at a time when so much nonsense is being produced elsewhere. The solution is obvious: we must have two publications—the *Journal*, and a more popular magazine, the new *Spaceflight*.

Spaceflight is a new venture. Our aim is to give our readers a picture of the research now going on, as well as discussing related historical and astronomical matters. Our first number is a typical "mixed bag". The introductory article by W. N. Neat will clear up a number of popular misconceptions—it is amazing how often the ancient and hoary space-gun rears its head!—and the principles of the rocket motor are explained by D. Hurden; there is a major contribution from K. W. Gatland on the subject of the new Earth Satellites which are now so much in the public eye. Dr. Slater's article deals with Mars, and this is most topical, since in September, 1956, Mars was closer to us than has been the case for many years. G. V. E. Thompson has given us a brief biography of the strange, unconventional Russian with the somewhat Ruritanian name of Konstantin Eduardovitch Tsiolkovskii, who was almost the first man to realize that when space is crossed, it must be by means of the rocket. And many readers will, it is felt, make use of A. V. Cleaver's book guide.

Lighter features have not been neglected. Some people may well have red faces after reading the contribution from P. E. Cleator on *The Hum and the Bug*, and cartoons too have been included.

For the moment, it is planned to issue *Spaceflight* four times per year, though this depends on your support. So much research is now in progress that each issue is certain to contain new information.

Some articles will of course be commissioned by the Editorial Board, but unsolicited articles will be very welcome. The technical level required can be judged from the papers in this first issue. Constructive criticisms will also be welcome. If a letter is intended for publication, it should be so marked.

By issuing this new periodical, we consider that the Society will be better able to play its part in the spreading of knowledge. There is a real need for this, particularly since so many strange theories still persist (to say nothing of flying saucers and other space-borne crockery). We hope to enlarge our scope as time goes on. Meanwhile, we hope that this first issue will meet with your approval.

PATRICK MOORE,
Editor.

Glencathara,
Worsted Lane,
East Grinstead,
Sussex.

A Message from F. C. DURANT III, President of the International Astronautical Federation

It was with pleasure that I learned of the intention of the British Interplanetary Society to publish a popular periodical entitled *Spaceflight*. The B.I.S. has for many years been a leader in the education of the public on the subject. To many of the scientists and engineers actively concerned with rocket and guided missile projects, the importance of the layman's education may not be obvious.

However, with the first satellite vehicles to be launched in the next few years, there is every indication that man will travel in satellite flight within a decade. Circum-lunar flights and lunar landings will in all probability be shorter incremental steps. This evolution from aeronautics to astronautics involves many disciplines. The complexities of many technologies and sciences are involved.

The public is caught up in this age-old dream of space flight. They want to understand what it is all about. Newspapers and popular writers often fail in explaining it because the writers have not themselves been educated in the fundamentals. It is for this reason that I predict a successful future for your publication, and believe that it will fill a real need.

F. C. DURANT III,
President, I.A.F.

A Message to Our Readers

By R. A. SMITH, Chairman of the British Interplanetary Society

Twenty years have passed since I first joined the Council of our Society, and during that period there has been a profound change of opinion as publicly expressed by qualified men on the subject of interplanetary travel, While it would be too much to claim that this change is the direct result of the activities of our Society, there is a connection, for the development of the rocket which has led to this improved situation, has been the result of the work of rocket pioneers who were first attracted to this field of study because it provided a possible means of crossing space. Many of the world's leading figures in rocket development are avowed interplanetary enthusiasts and quite a few of them are drawn from the ranks of the brave few who dared to differ from the accepted scientific view of the time.

Whatever the cause, the fact is that the first of our Society's aims has been achieved. It is now widely understood that the rocket provides a means of propulsion in the absence of a surrounding medium, and is thus potentially capable of crossing the inter-planetary vacuum. Further evidence that this side of the Society's work has been well done lies in the number of good and accurate books that are now available to the public.

In the Council's periodic reviews of the current situation, consideration is given to how the Society can best serve the purpose of its foundation under the prevailing circumstances, and it has been necessary to take into account that the rapid development of the rocket during the war period, while we were inactive, has now advanced the subject of rocket research to a point where the Society can no longer hope to make a direct contribution as a corporate body, in the practical sphere, as did the American and German societies in their early years, and must rely more on the indirect method of reporting current developments, than on field work.

What has happened, in fact, is that many of our early members have taken employment in the growing rocket industry, or in the allied fields of servomechanisms, electronics or atomic energy, and are professionally making a more effective contribution than they could have hoped to do through the Society directly, as a body. Unfortunately much of this work comes under security classification, and they are thus deprived of the opportunity of public discussion which might lead to a beneficial exchange of ideas. Although this is a fact to be deplored, it must be accepted as an unfortunate necessity. None of us would wish to be party to any unintentional or premature disclosure which might hamper those charged with the responsibility of the defence of this country.

Thus the publications of the Society are limited to such information as becomes available from time to time on declassification, and we make this available as promptly as possible. A further difficulty arises in the fact that with the rapid development of the subject it becomes necessary for the specialist in each field to adopt a method of expression enabling him to express the niceties of meaning accurately to his fellow workers in the same field, but with increasingly specialized meaning, possibly unintelligible to others.

Thus the papers read, and the communications made to the Society, have tended to be addressed mainly to colleagues in the same field, and have lost a lot of their general interest. It is a matter of some concern to the Council that we have become aware of this difficulty, yet cannot meet it by publishing "popular" versions of these papers in the *Journal* without undermining its usefulness to the professional worker and its standing as a scientific publication.

It has therefore been decided to segregate the two sides of the Society's activities by producing this additional publication.

We feel it is justified because of the increasing urgency of the situation. With the announcement of the plans for the launching of the first satellite vehicle, it is obvious that the rocket age is drawing near. Very soon it will be possible to carry a payload from any place on the Earth's surface to any other part within the hour; very soon after that to send a rocket to the Moon, and, when sufficient experience has been gained in returning to the Earth's surface from outside the atmosphere, men will follow. It is in the public interest that the true significance of these developments should be as widely known as possible, so that exaggeration can be countered, and the correct information disseminated. That the rocket should be used, rather than be misused, is a matter of public responsibility which is beyond the more limited sphere of the specialist. It is essential that the opinions of the technician are given due weight, and that they should be considered against a background of soundly formed public opinion. It is one of our prime duties to assist in the formation of that soundness of public attitude to rocket research and development, without which there is a grave danger of misapplication of this new found liberty of motion. In this case, because of the existence of our Society it is possible to anticipate future developments and ensure that they have had sufficient prior publicity to enable mankind to do better than it has done yet with Atomic Energy, for instance. To exert this influence for good we must strive to place the facts before the public in a form that can be understood, and by carefully considering what we place before them, so that it is free of exaggeration or misrepresentation, create a reputation for accuracy and lucidity that commands respect.

A technical advisory committee has been formed, charged with the responsibility of translating technical language into the popular idiom without losing anything of general significance or accuracy. To do this will be no easy matter. You will be our judge. If you find this publication interesting, lucid and informative, we will have succeeded.

Flight into Space

By W. N. NEAT, B.A., A.F.R.AE.S.

What do we mean by "interplanetary travel"? What are the principles behind it, and what methods must be used?

The problems which must be solved before interplanetary flight is possible are both many and varied. Without doubt they will require the utmost effort and ingenuity of the engineer, the chemist, the physicist and the physiologist, as well as experts in many other specialized fields.

In plain and simple language, however, the most fundamental problem which faces us is that of overcoming gravitational force, that of the Earth in the first place and then that of the Moon or the planet which we wish to visit and from which, in due course, to return. Until this force is conquered we shall be limited to operations within the atmosphere, with but occasional brief excursions beyond it.

There have, indeed, been many suggestions as to how gravitational force might be overcome—writers over the last few hundred years have been most prolific and novel in their proposals. Among those which have been least impracticable have been enormous guns and catapults many hundreds of feet long. A brief study of their mechanics reveals that they would have had a most devastating effect on the projectiles they fired, even if the guns or catapults themselves could have been built. Numerous anti-gravity devices and substances have also been invented, but once again, even a cursory study has always shown that they were completely at variance with proved scientific laws and could never have worked.

One is on safe ground by stating that with our present knowledge, the rocket engine is the only propulsive device which can make interplanetary flight possible. One cannot say that some other and possibly far more revolutionary method of overcoming gravity will not some day be discovered; but if so, then it will almost certainly be based on some fundamental knowledge not yet within our grasp.

The rocket engine differs from other means of propulsion in that it does not depend on its surrounding medium for its method of operation. It carries all its means of propulsion within itself, and consequently works just as efficiently in the vacuum of interplanetary space as it does near the surface of the Earth, a property which is obviously necessary for operation beyond the limits of the atmosphere.

The rocket engine is, however, a reaction device, obeying all the well-known laws of mechanics; it derives its thrust by ejecting rearwards a stream of gas at an extremely high velocity. A turbojet does much the same, except that it draws in the bulk of this gas stream from the atmosphere before compressing it, burning a fuel with it to heat it, and then ejecting it rearwards. The rocket engine does not do this (it would not be much use for interplanetary flight if it did), but instead derives the whole of its propulsive gas stream from chemicals it carries with it. These chemicals, which are generally stored in liquid form, are known as propellants.

The overriding disadvantage of the rocket engine is that a great mass of propellants is required, and this is perhaps the greatest single difficulty in achieving interplanetary flight, since all the propellants required for a voyage in space have to be carried up from the surface of the Earth. Their amount will depend on how fast the spaceship has to go, since this will decide the size of its rocket engines and the length of time for which they have to operate. The velocity a spaceship is given will itself depend on where we wish to go, but is so high that even for the simplest missions, large quantities of propellants have to be carried, which in turn will result in a spaceship of quite staggering size.

The magnitude and difficulty of any voyage into space can be assessed by the sum of the various velocity changes which the spaceship has to be given. For example, to establish an expendable satellite 200 miles high, a velocity of about 10 km./sec. would have to be attained. For a one-way trip to the Moon, about 17 km./sec. would be required, but for a voyage to the Moon *and back*, a total velocity of 25 km./sec. would be needed. This last figure is made up of so much velocity to escape from the Earth's surface, so much to land on the Moon, so much to take off again and then so much to land back on the Earth. So far as the magnitude of the task is concerned it does not matter whether velocity is given to the ship or taken from it—in either case its rocket engines have to be operated, and propellants are used up which were contained in the ship and carried on the voyage.

In practice, all velocity changes during a voyage would be made as quickly as possible to avoid having to carry propellants any farther than is absolutely necessary. For example, during the take-off from the Earth's surface a ship would be given its required velocity as quickly as possible, subject, of course, to acceleration and atmospheric heating effects being acceptable. After the necessary velocity was obtained, the rocket engines would be stopped, and the ship would coast in space gradually losing velocity under the influence of gravity.

The amount of propellants which are required depends not only on the total effective velocity which has to be given to the spaceship, but also on the efficiency of the rocket engine itself. The rocket engine's efficiency

depends almost entirely on the velocity at which the burnt propellants are ejected—the higher this velocity, the more reaction is obtained from each ton of propellants burnt, and the more efficient the rocket motor.

Propellants which are in common use to-day (e.g. liquid oxygen and petrol) yield exhaust velocities of the order of 2½ km./sec. More advanced combinations such as liquid fluorine and liquid hydrogen, on which some experimental work is already being done, give velocities approaching 4½ km./sec. This figure is roughly the limit we can expect from chemical rocket engines—i.e. those which derive their power purely from the chemical energy of their propellants. Their highest performance is achieved at the expense of considerable technical difficulty. This arises from the high temperatures at which these propellants burn which impose very difficult problems of combustion chamber design. In addition, such chemicals are corrosive and toxic and in other ways equally unpleasant. Even so, work is going on to make such combinations usable by overcoming their engineering and chemical problems.

To change the velocity of a spaceship, the rocket motors must be turned on so as to eject a stream of exhaust gases at high velocity in the direction opposite to the desired change. By applying Newton's laws of motion it can readily be shown that the ratio of the velocity change produced to the exhaust velocity equals the natural logarithm of the ratio of the spaceship masses before and after the manœuvre.

Thus if the velocity change is to equal the exhaust velocity, the "mass ratio" must be 2·7183, the transcendental number which is the base of the natural logarithms. This means that of every 2·7183 tons before the manœuvre, 1·7183 tons must have been propellant used up to effect the desired velocity change. To double this velocity change, the mass ratio must be squared (7·389); to triple it, the mass ratio must be cubed (20·080) and so on.

We can see that the largest possible value of the mass ratio is the mass of the rocket full of fuel divided by the empty mass (which must include the rocket structure, the empty fuel tanks and the motor itself, as well as the payload of men or instruments). When all the propellant is used up, the rocket has been given its maximum, or terminal velocity. With the best engineering practice, using the lightest and strongest materials of construction, the best mass ratio so far achieved has been in the neighbourhood of 4 (the Viking rocket), and it is very difficult indeed to envisage a rocket in which more than 9/10 of the mass is fuel, leaving only 1/10 for everything else. Clearly this represents an absolute limitation of rocket performance, and we cannot expect any rocket to generate a velocity much greater than twice its exhaust velocity.

This limitation can be avoided by making the payload of one rocket another smaller rocket. Thus the small rocket is carried to the terminal velocity of the larger or first stage rocket, and is then detached from the useless mass of empty tanks and structure and accelerates to its own terminal velocity. In this way the terminal velocities are added together, and in theory there is no limit to the velocity which may be reached with a step-rocket, simply by increasing the number of steps. In practice, each extra step multiplies the total weight by a factor of up to ten, so that for reasons of sheer bulk rockets of more than five stages are not often contemplated.

Even assuming the use of the step principle, however, and taking into account all other matters like air resistance and allowances for navigational errors, the mass ratio equation reveals that chemical rocket engines, even of the most advanced type, will not permit any more than the establishment of an Earth satellite vehicle in its orbit. That is to say on a reasonably practicable basis—it would still be possible to land a small payload on the Moon, although the ratio of this to the initial weight of the projectile would be very small.

The use of nuclear power alters the picture to a considerable extent. If heat energy is derived not from the chemical reaction of different substances, but from an atomic pile, it is possible to choose the most convenient working substance, heat it up in a pile to a temperature possibly higher than that obtainable by chemical means, and then expand the hot gas formed through a propulsive nozzle. By doing this, exhaust velocities greater than 10 km./sec. can be obtained, with obvious effect on the practicability of any mission into space. As a further possibility, it is conceivable that charged particles of matter could be accelerated, using a nuclear source of power, up to velocities approaching that of light. Such a device would give a performance many times more effective than present day chemical rocket engines.

The problems involved in such developments should not be underestimated. The difficulties of operating an atomic pile at the high temperatures required are away beyond our current achievements while the problems of waste heat dissipation in the ion rocket are formidable. Even so, it is quite conceivable that these problems will be overcome, and that the nuclear powered rocket engine in some form or another will be used for flight to the Moon and the planets.

When is work going to begin on an interplanetary project? The answer to that question is that, in effect, it already has. For example, all the work which is being done on rocket engines for the assisted take-off and main propulsion of aircraft, for large offensive weapons like V-2 and research rockets like Viking and many other projects about which little or nothing as yet has been revealed, is all strictly relevant. This work will, of course, have to be extended considerably to meet interplanetary needs, but the seeds have already been sown and a great deal of knowledge and experience harvested. In the same way, all the work which has been done on the structural problems of large missiles or on large and fast aircraft, including their pressurizing, heating and cooling systems, is the sort of background

knowledge invaluable for any interplanetary project. Similarly, all the work which has been done on missile guidance and control, on computing systems and navigational methods is of immense value, as also are the physiological tests carried out in pressure cabins and centrifuges, etc., to investigate the effects of high speed, high altitude flying on human beings.

It is the writer's opinion that after blending and elaborating all the knowledge and experience already gained, true interplanetary flight will result from a logical programme of steps, each one a stage more difficult than that preceding it. It is indeed very fortunate that interplanetary flight *can* be achieved in this way, since the experience gained on one step can be applied to the next, and so on.

The first steps such as the design and operation of comparatively short range missiles like V-2 and the vertical firing of research rockets have already been made. The next steps soon to follow will consist of long range missiles with much more sophisticated guidance systems and probably employing the multi-step technique for greater overall efficiency. In parallel with these military ventures, as already announced, efforts will be made to establish small satellite vehicles which will orbit round the Earth a number of times before losing altitude and finally being destroyed by aerodynamic heating. Although quite small, these satellites will serve an invaluable function in radioing back to Earth during their brief life, vital details of conditions at extreme altitudes.

They will also serve a useful purpose in providing the knowledge and encouragement necessary for the next step, which will be that of putting a manned satellite into an orbit round the Earth. This will probably remain aloft for some days, or even to begin with only hours, but will then return to Earth by using the atmosphere as a controlled breaking force, eventually to land in the same way as an aeroplane. Again important vital information will be amassed, information not only of the conditions in space but also of the technique of getting there.

After this the next stage will probably be the setting up of a more permanent satellite, a laboratory in space on which men can live and work for long periods of time. This will not only provide the means for learning a lot more about conditions in space, such as the nature and extent of cosmic radiation, but it will also demand the solution of many technical problems—the providing of a breathable atmosphere, even temperature conditions and a supply of water and food for the occupants, some protection against meteors and the production of a constant supply of power. Added to these are the basic structural problems of the station and the even more basic problem of building it. It is very probable that this operation will be carried out in the station's own orbit in space, components and equipment being taken up from Earth a little at a time by means of ferry rockets.

In all these respects the artificial satellite will be forerunner of a true space ship, since all the problems of the satellite will apply equally well to the ship itself. The satellite may be the forerunner in yet another respect since it appears quite feasible that it will be used as a "launching platform" for voyages into deeper space. The technique of building the satellite can just as well be applied to the building and fuelling of the spaceship. In this way the ship will begin its voyage already having orbiting velocity and will not itself have to carry up all its propellants from the surface of the Earth. This will mean a considerable and worthwhile reduction in the total velocity requirement for any particular journey, and as the mass-ratio equation shows, a reduction in the initial weight, cost and technical difficulty of the ship will result. At this stage, it is quite possible that a form of nuclear rocket propulsion will be used, and the improved performance obtained will further lessen the difficulties of the mission.

After the Earth satellite stage, the next target will almost certainly be the Moon. It is very doubtful if a landing will be attempted on the first voyage, during which the Moon would just be orbited, a return then being made to the Earth satellite vehicle. A landing will soon follow, however, to be followed by exploratory voyages to the planets. Whether we can land on all of them is improbable, but orbiting trips will be made to get a closer look and to assess the hostility or otherwise of their surface conditions.

It is very important that the difficulties of this long and complicated programme are not underestimated. It should also be realized that it will cost a great deal of money, while its rate of achievement will depend on economic, military and sociological factors.

The benefits which will accrue from the achievement of interplanetary flight will not be peculiar to that particular accomplishment alone. As a result of the research and development work which must necessarily precede its fulfilment, a great deal more will be learnt about the laws of physics, chemistry, and physiology, to quote but a few, together with a widening of our horizons in strictly engineering fields. It is inevitable that mankind must reap considerable benefit from all this effort even down to the simplest, most everyday and therefore most easily appreciated improvements in his general standard of living.

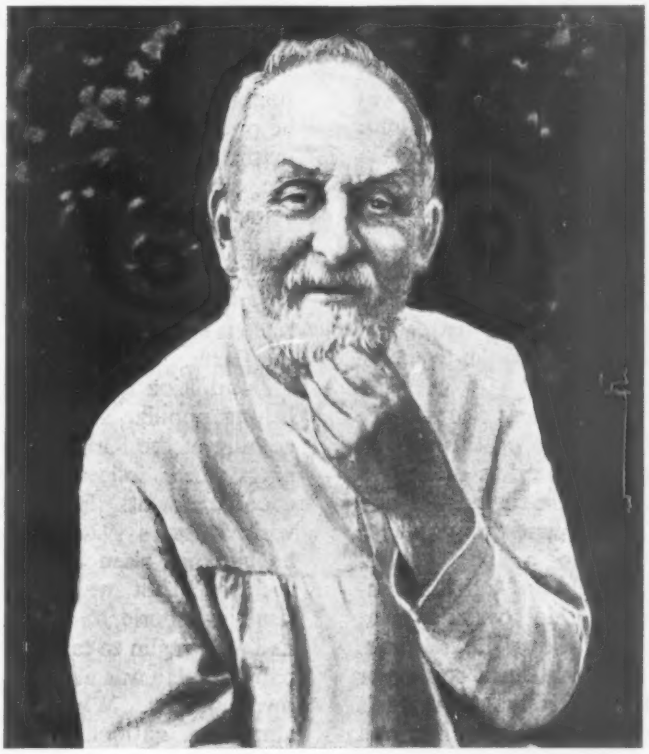
Tsiolkovskii — Founder of Astronautics

By G. V. E. THOMPSON, B.SC., A.R.C.S., F.R.I.C.

The life and work of the Russian scientist who realized the possibilities of rocketry in space-flight.

How and when did astronautics begin? Who first thought of space travel? Those questions, which spring naturally into the mind of anyone who becomes interested in interplanetary travel, seem to be closely connected. But the answers are quite different. Men have been thinking about space travel for many thousands of years; we can trace the idea back almost as far as the earliest records of man's history. But astronautics—the scientific study of space travel and all its problems—is a comparatively new thing. It may be said to date from the end of the last century.

There are some unfortunate people who like to argue over questions of priority, such as whether the calculus was devised first by Newton or by Leibnitz, who first invented radio, etc. They would enjoy discussing the origin of astronautics, for this also appears to have been conceived independently by two men at about the same time. The German inventor, Hermann Ganswindt, seems to have been the first to get his ideas into print, but he did not take the trouble to follow them up in any detail, and spent the latter part of his life engaging in numerous lawsuits and petitions. The other man is therefore usually thought of as the founder of astronautics. He was Konstantin Eduardovich Tsiolkovskii, a Russian of Polish descent; you will occasionally come across his name written in the German form, Ziolkovsky.



Tsiolkovskii.

Tsiolkovskii's father was a Pole who had settled permanently in Russia, a forester by occupation but more interested in philosophy and inventing. The son later wrote that he considered his father a failure, and his mother's family the more intelligent. He was born on September 5, 1857, in the village of Izhevsk, in Ryazanskii province. When he was ten he contracted scarlet fever; although he recovered he was left permanently deaf. This was to have a great influence on the subsequent course of his life. Apart from being unable to attend the ordinary school, he also became shy and sensitive, but with an ambition to make up for his disability by achieving distinction in some way or another. He educated himself; he read; he wrote bad verses; he constructed models—balloons, a winged flying machine, a carriage driven by a steam turbine, etc.

However, while he could be considered to be precocious in some directions, it is apparent that in others the boy was ignorant and quite naïve. Thus it was not until he reached the age of fifteen that he became acquainted with even elementary mathematics. At about this time he first conceived the idea of constructing a large balloon or dirigible with a metallic envelope. This idea was one to which he was to return again and again throughout his life. In his autobiography he also mentions that when he was sixteen he began to think of applying centrifugal force to the ascent into space. One evening when he was staying in Moscow he could not sleep because he imagined that he had perfected such a method of interplanetary travel. He strolled about Moscow all night thinking about the consequences of his supposed discovery, but with the coming of the dawn he realized his mistake, and the disappointment was just as great as his previous elation. The memory of that night remained with him throughout his life; and even after fifty or sixty years, in his dreams he sometimes imagined himself rising in the centrifugal machine towards the stars and planets. This experience made him realize the gaps in his knowledge, and he began to study higher mathematics. He actually became a mathematics and physics teacher, and remained so for nearly forty years.

When Tsiolkovskii was about twenty-four, he submitted to the St. Petersburg Physico-Chemical Society various papers he had written on the theory of gases, biology, stellar radiation, etc. They were received by the eminent scientists with some surprise, because while they purported to contain the results of original investigations, in reality they covered the same ground as theories set forward many years previously by other people. A closer study of the manuscripts revealed that they had been written by someone ignorant of the earlier work. The discoverer of the periodic system of the chemical elements, Mendeleev, himself wrote to Tsiolkovskii on behalf of the Society to explain the position to him. This was evidently done with tact and understanding, for Tsiolkovskii did not give up his scientific investigations.

He carried out experiments on steam engines for a time, but then returned to the theoretical study of the metallic dirigible. In 1887, his first published communication on the dirigible appeared. Mendeleev was interested in this work and helped Tsiolkovskii. Thus through his agency, Tsiolkovskii was able to present a paper on his aeronautical work to the Imperial Russian Technical Society in 1890; he also submitted a model of the dirigible. In 1891 he built a small wind tunnel to carry out air resistance experiments on his airship models. The account of this work was eventually submitted to the Imperial Academy of Science, who regarded it favourably and made him a grant of 470 roubles to enable the experiments to be continued.

Meanwhile he had not given up his ideas about space travel. A popular account of his views on this subject was first published in 1895, and a more detailed survey of a liquid-fuelled spaceship was prepared in 1898 and eventually published in 1903. This first design was a streamlined shape divided up into a long conical combustion chamber, propellant tanks and a living compartment. It embodies one of Tsiolkovskii's great contributions to astronautics—the use of liquid fuels. The small rockets previously used had burnt cordite or some similar powder fuel, but he realized that liquid fuels are capable of producing higher exhaust velocities and thus exerting greater thrusts. Another advantage of liquid propellant engines is that it is possible to exercise more control over their operation; they can be started, stopped and re-started as and when required, and their thrust can be varied if necessary. The flight programme of a simple powder rocket cannot be varied once it has been ignited.

During the next quarter of a century, Tsiolkovskii brought out various other designs for rocket-propelled spaceships. They were not intended as working drawings for the construction of these vessels, but rather as a rough guide to the equipment and facilities that would be needed. Some of them are grotesque and even ludicrous, but others are now standard practice in the guided missile field. Thus there is the insertion of control surfaces into the jet of exhaust gases leaving the engine; by tilting the surfaces the exhaust is deflected and simultaneously the rocket itself begins to change course. This method of steering was later adopted in the German V-2 (or A-4) missile. The suggested propellants (liquid hydrogen or hydrocarbons with liquid oxygen) might almost be considered to be conventional. It is true that liquid hydrogen has not yet been employed on a large scale, but it has been used experimentally. Hydrocarbon fuels (kerosine, etc.) are fairly common, and liquid oxygen is the most widely-used oxidant for rocket engines.

However, Tsiolkovskii's claim to fame does not rest solely on these proposals. During the period 1903–26 he published several articles and books dealing with the mathematical theory of rocket flights and space travel. He obtained equations enabling us to work out the velocities and expenditure of energy needed for flight along different types of path, the effect of air resistance, the times of flight, etc. His calculations showed that it would be perfectly possible to travel out into space in rockets and even to set up manned space stations around the Earth.

In addition to this theoretical work, he was also publishing popular articles and even science fiction. The coming of the Russian revolution did not interfere with his studies; indeed he seems to have received some encouragement. Evidently it was not as much as he wished, for in 1926 we find him bewailing the fact that he had not risen in the world and had not had real success. That was hardly true; following his lead, Esnault-Pelterie, Goddard, Oberth and other pioneers had also begun to tackle the unsolved problems of astronautics. He was also beginning to be well known in his own country. When he reached 75 in 1932 he was almost a national hero. Articles about him were published in the Soviet newspapers, and Osoaviakhim, the State aviation organization, arranged celebrations of his birthday. A telegram of congratulations was also sent to him by Stalin himself. Recent political events might lead the reader to wonder whether that can be considered an honour, but at the time it was evidently a mark of recognition by the State. Tsiolkovskii died in 1935.

Ideas Behind the Rocket

By D. HURDEN, B.A., G.I.MECH.E.

How a rocket works, and why it is so important in all studies of interplanetary flight.

The newspapers to-day contain frequent reports of guided missiles that have been made or are believed to exist. This issue of *Spaceflight* contains an article on the American artificial satellites. Children's papers run serials on interplanetary enterprises, and even the B.B.C. has its "Adventures into Space". All these feature rockets in one form or another, so perhaps it is worth pausing for a few moments to consider what a rocket really is, how it works, and what its limitations are.

A rocket is simply a jet propulsion device which burns a fuel of some kind to produce gases which are expelled rapidly backwards. Now according to that fundamental law of mechanics, Newton's Third Law of Motion, action and reaction are equal and opposite, so that although the rocket exerts a force to drive out its products of combustion, they in turn exert an equal force in the opposite direction to drive the rocket (and whatever may be attached to it) forward. In spite of valiant efforts by scientific correspondents it is still unfortunately believed by many people that jet engines derive their thrust from the push of their exhaust gases against the air. This is just not true. They are merely another demonstration of Newton's Third Law quoted above which does not depend on the presence of air for its truth. The consequences of this law are felt whenever we throw a cricket ball, for example. The harder we throw the ball, the greater is the tendency for us to overbalance backwards. As we exert a force to throw the ball away from us, it exerts an equal and opposite force on our hand which tries to make us stagger backwards. As a final example of the use of this principle, let us consider the unfortunate plight of a man marooned in the middle of a perfectly frictionless and impenetrable sheet of ice. Because it is frictionless he cannot walk off: because it is impenetrable he cannot skate off. However, if he throws off his shoes he will expel mass with velocity relative to himself and will thus slowly but surely propel himself in the opposite direction.

It may perhaps be worth mentioning at this point that the fact that a rocket will continue to exert a thrust in a near-vacuum was demonstrated experimentally in 1916 by Dr. R. H. Goddard.

So far our definition of a rocket would apply equally to the better known aircraft jet engine. The latter works by drawing in air from the atmosphere, compressing it, heating it by burning fuel in it, and expelling the hot gas as a propulsive jet. The oxygen needed to burn the fuel is thus supplied from the atmosphere, and if there is no atmosphere the fuel will not burn and the engine ceases to work. The rocket, on the other hand, carries the oxygen needed to burn its fuel with it. This behaviour leads us to the very important conclusion that a rocket will still act as a jet propulsion engine in space, where there is no atmosphere.

The fuel and oxidizer of a rocket (collectively called propellants) may be either solid, liquid, or gaseous. Life-saving rockets, the familiar Fifth-of-November rockets, and some assisted take-off rockets for aircraft use solid propellants. Typical solid fuels are charcoal and asphalt, while the oxygen to burn them is supplied by oxygen-rich substances such as potassium nitrate or potassium perchlorate. Common liquid fuels such as petrol, kerosine, or alcohol may be used in rockets and burned either with liquid oxygen itself or with such strong oxidizers as hydrogen peroxide or nitric acid. Gaseous rockets are of little practical use owing to the great amount of space needed to store even a moderate amount of propellant, but rockets have been made for research purposes to burn hydrogen or methane with gaseous oxygen.

Solid-propellant rockets commonly burn for only a few seconds, and once started cannot be stopped. They present many interesting problems, but of a somewhat specialized nature. Gaseous-propellant rockets are for most purposes impracticable. Liquid-propellant rockets can be used for propelling aircraft and missiles and possess many interesting engineering features, so it is with this type that we will principally concern ourselves.

Having established the principle on which a rocket works, let us try to form a better idea of what such a device looks like. From the cricket-ball analogy we may guess that the faster the gases are ejected the greater will be the thrust produced. It is also common experience that air or any other gas contained in a vessel will escape from a hole in the vessel faster when the pressure is high than when it is low. We may therefore imagine a rocket to be something like the object shown in

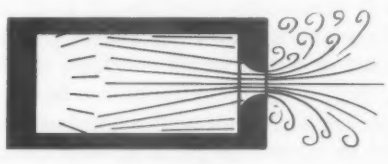


FIG. 1*a*. Simple rocket

Fig. 1*a*, consisting of a cylindrical container in which propellants are burnt at as high a pressure as convenient

and from which the gaseous products of combustion escape through the hole in the end to form the propulsive jet. Such a device is in fact a crude rocket and does not differ much from the powder rockets made up to the beginning of this century. However, gas escaping from such a hole still possesses energy in the form of pressure, and if we suppose the fuel to be burning at a pressure of 300 lb./sq. in. the gas flowing through the hole will be at a pressure in the region of 160 lb./sq. in. The gas will expand from this pressure down to the external pressure in random directions and will dissipate much of its energy as eddies. Suppose now that a conical nozzle is added as shown in Fig. 1*b* so as to provide a

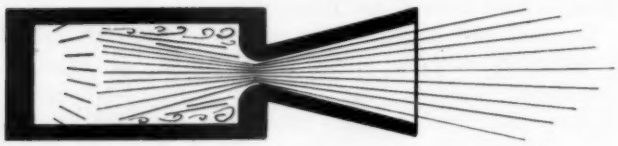


FIG. 1*b*. Simple rocket improved by adding expansion cone

passage of steadily increasing area. As the gas flows through this passage its pressure will fall and it will expand, but it is constrained from expanding sideways by the walls of the nozzle and must therefore move in a direction roughly parallel to the axis of the rocket. The nozzle can be designed so that the gas leaving it is at the external pressure, and therefore leaves it without serious loss of energy in an almost axial direction and at a considerably higher speed than when the "expansion nozzle" is not used. This principle has been used for many years in the design of nozzles for steam turbines, and some idea of the advantage to be gained is given by the fact that steam expanding through a plain nozzle from a pressure of 300 lb./sq. in. to atmospheric pressure of 15 lb./sq. in. leaves the nozzle with a velocity of about 1,740 ft./sec., which is increased to about 3,420 ft./sec. by adding a properly-designed expansion cone.

It seems therefore that if we burn our rocket propellants in a combustion chamber shaped something like Fig. 1*b* we shall get our high-speed jet of gases. Unfortunately there is another complication. We have seen that it is desirable to burn the fuel at a high pressure, so for strength reasons the combustion chamber should be made of metal. Alcohol burns with liquid oxygen at a temperature of about 2,800° C., while steel melts at a temperature near 1,400° C. Unless we can keep the combustion chamber cool, it is obvious that it will rapidly melt. This is commonly done by an extension of the principle of cooling a motor-car engine by surrounding it with a jacket of liquid which conducts the heat away. In a rocket, one of the propellants can be made to flow through a jacket surrounding the combustion chamber on its way to be burnt. It picks up heat from the inner wall of the combustion chamber, and is continually replaced by more cool liquid. This system is called regenerative cooling, since heat which would otherwise be lost is picked up by the propellant on its way through the jacket and is returned when it enters the combustion chamber. In order to pick up enough heat from the inner wall to prevent it from melting it is usually necessary to speed up the liquid on its way through the jacket, since it is broadly true that the faster a liquid flows over a hot surface the more heat it will pick up. This can be done by making the liquid follow a spiral path, and one way of achieving this is shown in Fig. 2, which is a photograph of the inner shell of an experimental combustion chamber.

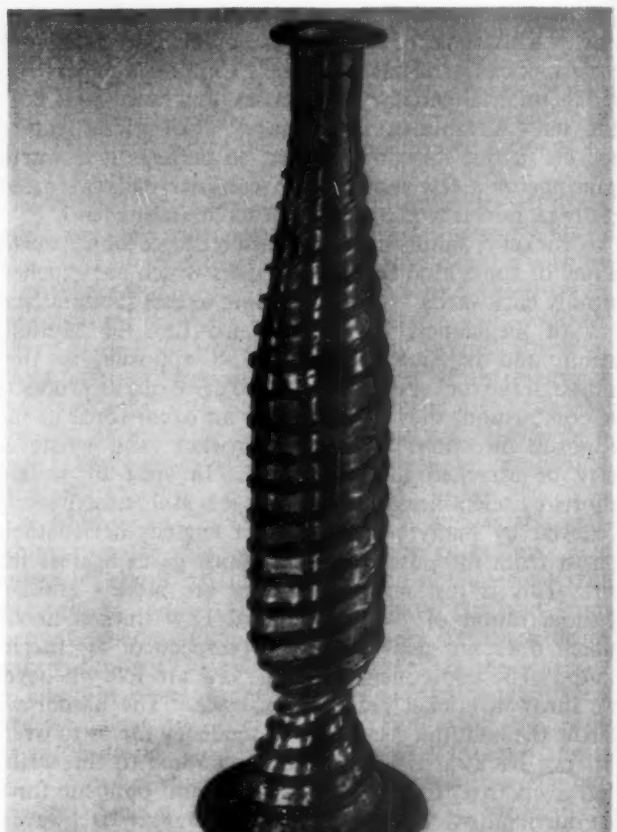


FIG. 2

A section through the middle of a typical liquid-propellant combustion chamber is illustrated in Fig. 3. It shows two important features of the combustion chamber which have not so far been mentioned—the injector and the igniter. The injector, as its name implies, is the means of introducing the propellants into the chamber. In order to burn a liquid fuel quickly and efficiently it must be converted into a mist of very small droplets and supplied with the oxygen it needs for combustion. The injector therefore has the dual job of spraying both the fuel and oxidizer into the combustion chamber as finely-divided mists and mixing them in the correct proportions to burn. Dozens of different kinds of injector have been tried, some spraying the propellants in jets, some in thin sheets, some in conical sprays. Different propellants

need different types of injector, and the only certain way of choosing an efficient one is to test several which may look equally promising on paper and find out which gives the best performance in practice. The chamber

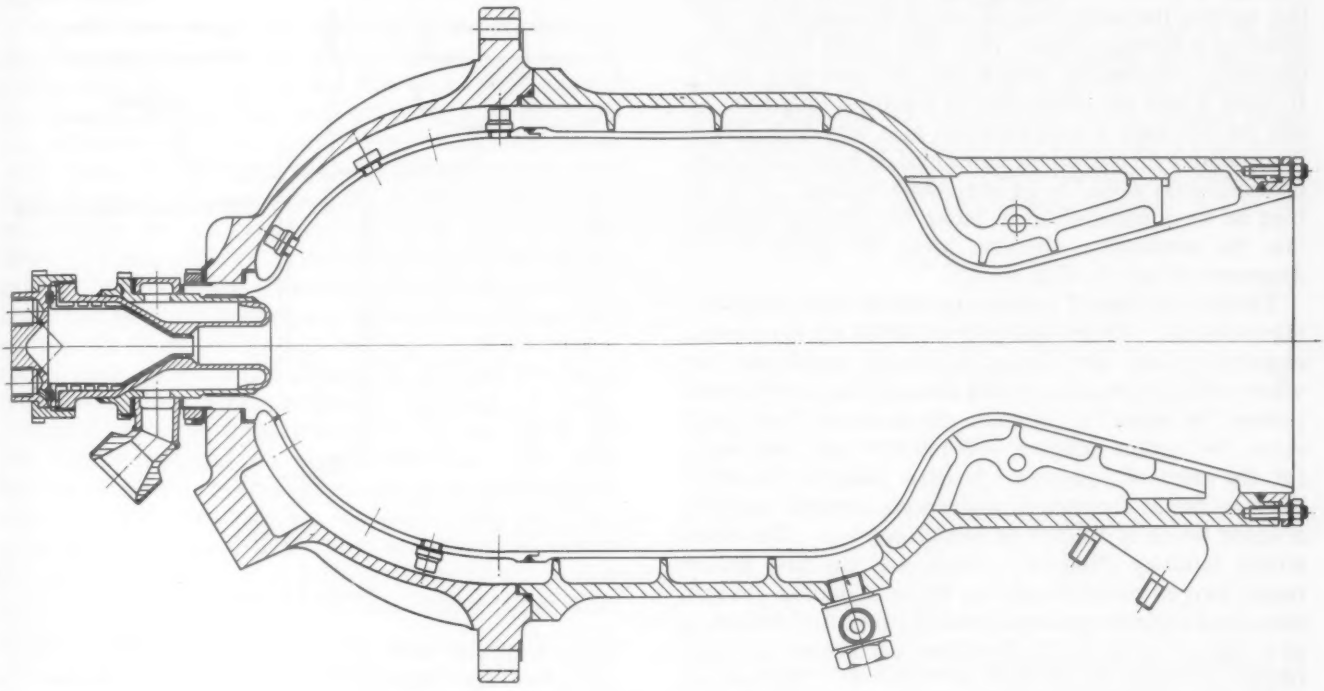


FIG. 3.

illustrated in Fig. 3 was cooled by alcohol which was injected as a number of hollow conical sprays from small injectors distributed over the front end. Liquid oxygen was injected from three rings of small holes surrounding the igniter, which was screwed into the middle of the same end.

Whether or not an igniter is needed depends on the propellants, some of which will ignite spontaneously on mixing. For instance, aniline and nitric acid will ignite simply on being sprayed together, but alcohol and liquid oxygen will not. If an igniter is needed it can take the form of a firework which is lit inside the combustion chamber—the German V-2 rocket was fired by a device like a giant catherine wheel—but this is either consumed or blown out when the rocket starts. Alternatively, it can itself be a very small liquid propellant rocket, capable of ignition by a sparking plug, which produces a pencil of flame to light the main stream of propellants. Such a device can be used as often as required, and the rocket may therefore be switched off and re-started. The combustion chamber in Fig. 3 is provided with such an igniter.

So far we have only described the combustion chamber of a rocket power plant, and while this is perhaps the most spectacular part, producing as it does the noise, flame, and of course thrust, there is much more that is of engineering interest. Let us consider what else is needed to supply the combustion chamber with the propellants it consumes. The propellants themselves of course will be stored in tanks from which they must be transferred to the combustion chamber. We have seen that they may be burnt at a pressure of several hundred pounds per square inch, and they must therefore be forced into the chamber against this pressure. There are two main

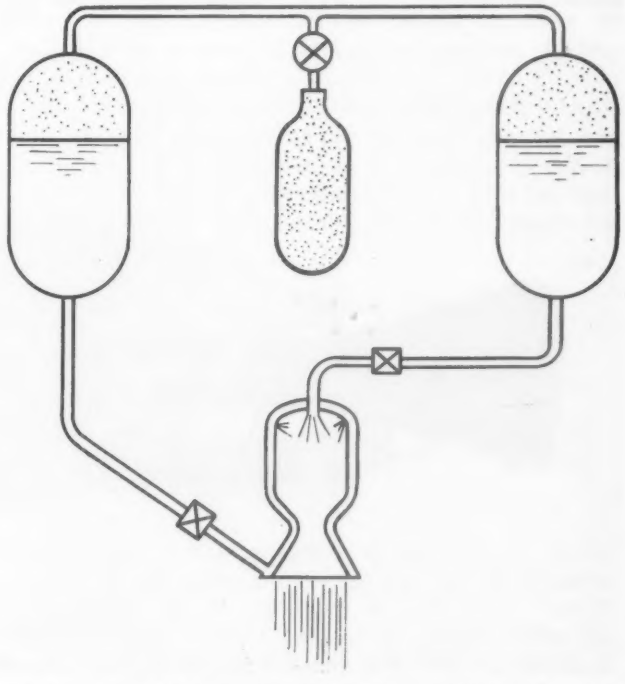


FIG. 4. Use of high pressure gas to feed propellants into rocket combustion chamber

ways of doing this, the simplest of which is shown diagrammatically in Fig. 4. In this method the propellants are displaced from their tanks by a gas such as nitrogen, which is stored under high pressure and fed to the tanks through a pressure-reducing valve. In order to apply this method the tanks must of course be capable of withstanding a pressure higher than that in the combustion chamber; this usually means that they are very heavy. In cases where the rocket has to run for a long time, or else for not such a long time but at a very high thrust, the quantity of propellant consumed is large, and high-pressure tanks would be an impossible burden. It would then be more economical to pump the fuel and oxidizer into the combustion chamber using the system shown diagrammatically in Fig. 5.

The introduction of pumps can lead to many engineering problems. Centrifugal pumps, which are in common engineering use, are almost invariably employed, but where orthodox practice would demand the use of several pumps "in series" to generate the necessary high pressures, the rocket designer will tolerate only one pump for the sake of lightness. Such a pump is therefore likely to run at abnormally high speed, perhaps pumping a liquid which is difficult to handle anyway. The Armstrong Siddeley "Snarler", which was the first British liquid oxygen rocket motor to fly in a piloted aircraft, contained a pump rotating at 14,000 r.p.m. and delivering at a high pressure about 30 gallons per minute of liquid oxygen, a liquid which boils at -183° C. To mention only one of the difficulties which arose, all normal lubricants freeze at temperatures well above this. Moreover, the use of pumps means that some way of driving them has to be found. The V-2, which ran for only 60 seconds, contained a turbine developing nearly 500 h.p. used only for driving its pumps. If a turbine is used, some means of starting it has to be devised and steam or other gas for driving it must be supplied. Turbine gas may be generated from the main rocket propellants

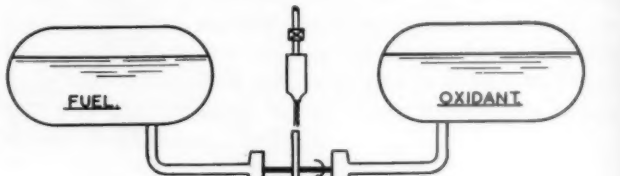


FIG. 5. Pump-fed rocket motor

using a special form of combustion chamber; alternatively hydrogen peroxide can be made to decompose into superheated steam and oxygen. Finally, the propellants for the combustion chamber itself, for the igniter, and perhaps for a turbine have to be regulated by a system of valves, the complexity of which depends on the form of the power plant and the nature of its duty.

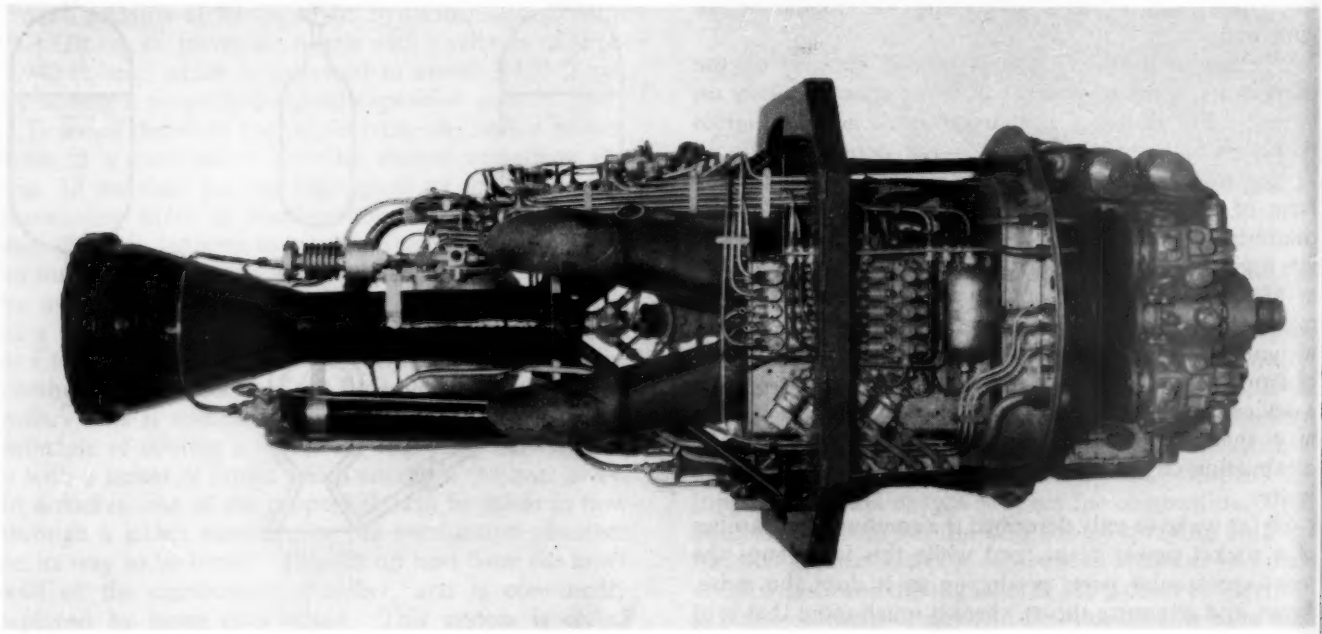


FIG. 6

We can see then that from a very simple conception the liquid propellant rocket motor has grown into a power plant at least as complex as the aircraft gas turbine. Fig. 6 gives some idea of the appearance of a complete rocket engine.

We now have some idea not only of the principle on which a rocket works but also of what it looks like. Let us now try to form some idea of its performance, how it may be improved, and what obstacles lie in the way of improving it still more. First of all, what do we really mean by the "performance" of a rocket motor? Does it mean the same thing as "thrust"? If so, can we improve the performance merely by increasing the thrust? Returning for a moment to our cricket ball analogy, we know that it requires more effort to throw a heavy ball or stone as hard as a light one, and if we have grasped the principle we can see that the thrust from a rocket may be increased simply by pushing out more propellants. But what propulsion engineers are really interested in is the thrust developed by an engine fed with fuel or propellants at a particular rate. The yardstick by which the rocket engineer measures performance is the quantity called "specific impulse". This is defined as the thrust produced by burning one pound of propellants per second. Thus, if F lb. is the thrust of a rocket motor consuming W lb./sec. of propellants, the specific impulse I is given by

$$I = \frac{F}{W}$$

It can be shown that specific impulse is closely related to the velocity v of the jet leaving the rocket, since

$$I = \frac{v}{g}$$

where $g = 32{\cdot}2$ ft./sec.^{2}, the acceleration due to gravity.

From this argument we can see that the performance of a rocket motor can be improved by increasing the exhaust velocity. Before we attempt to improve it, let us see what has already been achieved. The table below lists the propellants used by several different rocket motors together with their theoretical performance, corrected to a constant combustion pressure.

TABLE I

Motor	Nationality	Fuel	Oxidant	v ft./sec.	I
109–509	German	C-stoff*	Hydrogen peroxide	6920	215
A-4 (V-2)	German	Ethyl alcohol	Liquid oxygen	7700	239
Snarler	British	Methyl alcohol	Liquid oxygen	7210	224
Corporal	American	Aniline	Nitric acid	7090	221

* 57 per cent. alcohol, 13 per cent. water, 30 per cent. hydrazine hydrate.

We can see immediately from this table that the choice of propellants affects the performance from the beginning, so we may think it possible to effect a great improvement if only we can find the right pair of propellants. Let us follow up this idea.

By indulging in some mathematics we can show that the exhaust velocity at sea level depends principally on three things—the combustion pressure, the combustion temperature, and the composition of the exhaust gases. The effect of pressure is rather complex and is best shown in Table II, from which we can see that the amount to be gained by raising this pressure becomes less as the pressure increases.

TABLE II

SPECIFIC IMPULSE FROM NITRIC ACID AND ANILINE AT VARIOUS COMBUSTION PRESSURES

Pressure lb./sq. in.	I
100	132
200	200
300	220
400	226
500	230
600	233

For a given combustion pressure the specific impulse also increases somewhat as the atmospheric pressure is decreased, for instance at great altitudes. The exhaust velocity, and hence the specific impulse, varies as the square root of the temperature and inversely as the square root of the average molecular weight of the exhaust gases. A high exhaust velocity would therefore be obtained from a reaction at high temperature producing gases of low molecular weight.

Now it is possible to calculate the combustion temperature and the composition of the products for any combination of propellants, so it is also possible to predict their value as rocket propellants. This has been done for many reactions, and a few of the results are listed below in Table III.

TABLE III

Fuel	Oxidant	Temperature	I	v ft./sec.
Petrol ..	Liquid oxygen	3020° C.	242	7800
Hydrazine ..	Liquid oxygen	2900° C.	264	8500
Hydrogen ..	Liquid oxygen	2940° C.	340	10950

It will be seen that the oxygen-hydrogen reaction, which is one of the best, gives a pleasingly high specific impulse. Unfortunately liquid hydrogen is difficult to handle since it boils at −253° C., about 40 degrees below the freezing point of air, and is only 0·07 times as dense as water, which means that tanks to contain it must be very bulky.

What does become apparent from these figures is that the chemical reaction giving one of the highest theoretical exhaust velocities represents an improvement of only about 50 per cent. on existing motors. Clearly then we are approaching the limits of performance obtainable from "chemical" reactions. If we want to do better still we must consider other ways of doing it.

It has been suggested that nuclear energy offers a means of reaching extremely high exhaust velocities. Combustion is merely a chemical reaction which produces gases of a certain sort at a temperature which is fixed. It is theoretically possible to use the heat generated by an atomic pile to vaporize a liquid (which we may call the fuel) and then to heat the vapour to any desired temperature. Thus we may choose a "fuel" such as liquid hydrogen—or even water—which has a conveniently low molecular weight, heat its vapour to a high temperature at a high pressure, and then allow the gas to expand through the normal sort of rocket nozzle. By heating hydrogen to 4,000° C. at 300 lb./sq. in. and allowing it to expand down to atmospheric pressure, a jet velocity of nearly 30,000 ft./sec. can theoretically be obtained.

Although the use of nuclear energy in this way removes the theoretical barrier preventing attainment of very high exhaust velocities, there are formidable practical difficulties to be overcome. It is difficult using present-day techniques for cooling combustion chambers to take full advantage of known propellant combinations. Gas temperatures of 4,000° C. will make this difficulty far greater. Neither is there any indication that nuclear engineers are within reach of the reactors and heat exchangers that will be needed to produce this gas. It seems therefore that the nuclear rocket motor, although a theoretical possibility, will not make its appearance within the next few years.

Radio Noise from Jupiter

By GILBERT E. SATTERTHWAITE, F.R.A.S.

Assistant Director of the Jupiter Section of the British Astronomical Association

In these days when so much attention is devoted to studies such as cosmology and astronautics, the more old-fashioned study of the planetary surfaces may seem very prosaic; nevertheless discoveries of great importance are sometimes made which emphasize anew the value of this work.

The most recent discovery, made by B. F. Burke and K. L. Franklin at the Carnegie Institution of Washington and confirmed by C. A. Shain in Sydney, is that the planet Jupiter is a source of radio noise; its emissions are intermittent and of a rather low frequency, but are often very intense. This major discovery has led to close co-operation between the radio observers and the Jupiter Section of the British Astronomical Association. A study of the visual and radio data thus obtained has provided some very interesting results. It has shown that the sources are localized in small areas of the Jovian surface. Derived rotation periods for the sources show that they are situated in the non-equatorial regions of the planet, since the rotation periods for these regions are appreciably different from those for the rest of the disc.

It has been shown that certain visible features, particularly the well-known Red Spot and three white spots which have been shown to have been permanent features of the Jovian disc for the past fifteen years, are the probable sources of at least the more recent radio emissions. No emissions have been found connected with the long-known Disturbance in the South Tropical zone. It is interesting to note that with this exception the probable sources are associated with the four most permanent features of the Jovian disc.

These recent events have greatly emphasized the usefulness of observations of the planetary surface features and of close co-operation between workers in different fields.

Readers desiring more detail are referred to the following:

B. F. Burke and K. L. Franklin, "Observations of a Variable Radio Source associated with the planet Jupiter," *J. Geophys. Res.*, 60, 213, 1955.

C. A. Shain, *Nature*, 176, 836, 1955, October.

C. A. Shain, "18·3 Mc/s Radiation from Jupiter" (to be published shortly in the *Australian Journal of Physics*).

A. F. O'D. Alexander (Director), Report of Jupiter Section on possible sources of Jupiter's radio noise in 1955, *J.B.A.A.*, 66, 6, 208, 1956, May.

The Vanguard Project

By KENNETH W. GATLAND, F.R.A.S.

The Earth Satellites that are to be set up within the next eighteen months; what they will look like, how they will be launched, and the uses to which they will be put.

Between July, 1957, and December, 1958, scientists of nearly forty nations are to co-operate in the biggest ever examination of the physical forces affecting the Earth. This period, known as the International Geophysical Year, will include studies of ocean currents, tidal forces, the Earth's magnetic field, sunspot activity, the radio-reflecting layers in the upper atmosphere, cosmic radiation, micro-meteorites, and a host of other problems that concern us about our planet, its restless atmosphere, and surrounding space.

To obtain direct measurements of upper air phenomena, the United States, Great Britain, Australia and France are to launch a number of high-altitude research rockets; these include Aerobee[1] and Aerobee-Hi[2] (U.S.A.) 80 miles and 180 miles respectively; the Gassiot vehicle[3] (Gt. Britain and Australia) 104 miles, later version 130 miles; and the Veronique[4] (France) 75 miles. As a further aid to these studies, the United States have announced their intention of establishing small, unmanned, artificial satellites at the threshold of space, an event of far-reaching importance in the development of astronautics.

The satellite project—called "Vanguard"—is a three-year programme sponsored by the National Academy of Sciences and managed, within the U.S. Department of Defense, by the U.S. Navy because of their prior experience with upper atmosphere research. The Naval Research Laboratory has fired, since 1946, twelve Viking rockets and a large number of the smaller Aerobee's.

The artificial satellites, taking the form of spheres approximately 20 inches in diameter, will be launched into orbits between 200 and 400 miles above the Earth by means of step-rockets. Most, if not all, will contain research instruments and a small telemetering transmitter for relaying information to the ground. The technique has already been perfected with high-altitude rockets, like the Viking,[19] from which instrument readings have been received from heights of over 150 miles.

The principle of artificial satellites is very simple. If a body outside the atmosphere is given a sufficiently high velocity parallel with the Earth's surface, it will remain in space balanced between its centrifugal force and the Earth's gravitational pull (Fig. 1). It is rather like a ball revolving on the end of a piece of string, if you think of the tension in the string as gravity. The fact that gravity decreases with distance from the Earth means that the velocity required—called *orbital velocity*—also decreases. Close to our planet, over the first few hundred miles, it is approximately 18,000 m.p.h. At 1,000 miles, it is approximately 15,800 m.p.h., and at 22,000 miles, the so-called "24-hour orbit", it has dropped to only 6,840 m.p.h. It should be explained that a satellite on a 24-hour orbit will make one revolution in exactly the time the Earth takes to turn on its axis; therefore, it will remain "fixed" in the sky relative to a fixed point on the Earth.

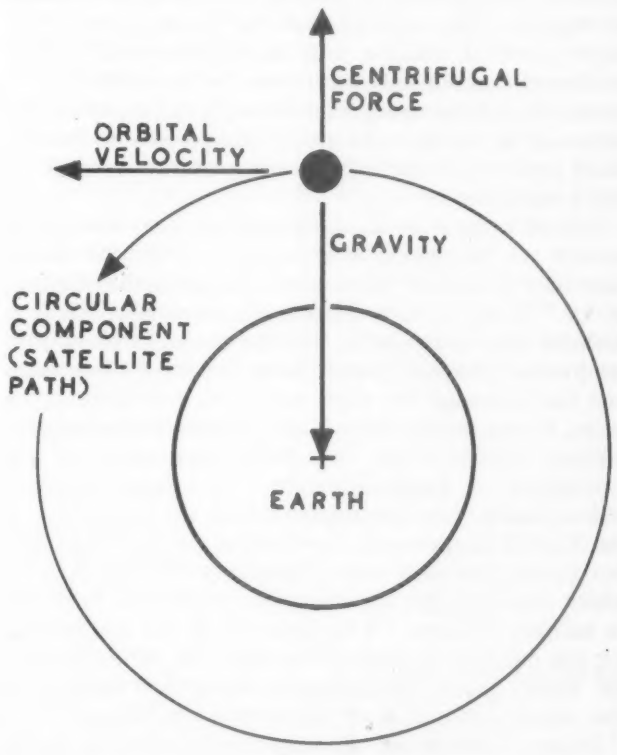


FIG. 1. Principle of the artificial satellite

The fact that the orbital velocity *diminishes* outwards from the Earth does not, of course, mean that it is easier to establish a satellite at a distance of 1,000 miles than it is at 500 miles. The launching vehicle in this case would have to do work *against gravity* over a longer period, and would require correspondingly *greater energy*.

HISTORICAL SURVEY

The history of artificial satellites, if only in terms of theory, dates back many years. Oberth,[5] "Noordung",[6] and von Pirquet,[7] gave consideration to "space-stations"

in the 1920's, proposing that they might be used as refuelling bases for spaceships, as astronomical observatories, and laboratories for physical research beyond the atmosphere. However, it was not until the end of the Second World War, largely as a result of the development of the V-2 in Germany, that the idea began to emerge as a practical engineering possibility. Dr. von Braun himself (co-designer of the V-2) laid emphasis on the development of man-carrying, multi-stage, satellite rockets in an interrogation report written in June, 1945.[8] This was a speculative idea based on some preliminary design proposals for large step-rockets (i.e., the fabulous A-9/A-10 project of 1942).[9]

However, it was not until detailed theoretical studies of the problem were made in the early post-war years that the small, unmanned, artificial satellite came to be recognized as the logical first step.

A theoretical study by Messrs. H. S. Seifert, M. M. Mills and M. Summerfield, entitled "The Physics of Rockets",[10] appeared in 1947 in the *American Journal of Physics*. This was followed, in the same year, by a paper by F. J. Malina and M. Summerfield,[11] which confirmed that not only was it possible to establish small rockets in circular orbits round the Earth but, by careful choice of the number of steps, it was possible to liberate small payloads from the Earth using conventional chemical propellants.

Official interest in artificial satellites was first made known in December, 1948, when the United States Secretary of Defense announced in Congress the existence of an "Earth Satellite Vehicle Programme".[12] It was revealed that investigation into the design of close-orbit satellite rockets had already been in progress two years and that although the work was in an early formulative stage, it was being carried out independently by each military service under the direct supervision of the Committee on Guided Missiles. A number of theoretical studies were undertaken within the framework of the RAND Corporation, a somewhat peculiar organization concerning itself with a miscellany of research tasks, which even includes the theory of games with reference to military strategy. One outcome of this programme for the purpose of determining optimum orbits close to the Earth, was a comprehensive theoretical analysis of the nature and extent of the Earth's atmosphere.[13]

Much of these initial activities was shrouded in secrecy but although it was later reported that certain aircraft companies* had played a part in the studies, there was no practical development, presumably because of the post-war emphasis on guided-weapons and the realization that the artificial satellite had little military value. It was left for the International Geophysical Year to provide the final incentive for work to proceed.

*It is of interest to note that these early studies, including work by Douglas, North American, and Aerojet, are still classified, whereas information on the current Glenn-Martin–Aerojet satellite project is being made freely available. This suggests that the original U.S. designs were for larger step-rockets than those specified for MOUSE and VANGUARD, which may still be relevant in connection with the inter-continental ballistic missile.

Theoretical Studies

It is pleasing to report that, when design specifications for America's artificial satellite were drafted last year, two British papers were among several theoretical studies taken into consideration for this project. One of these, presented on behalf of the British Interplanetary Society at the Second International Congress on Astronautics in London in 1951, laid emphasis on the structural design of *minimum satellite vehicles*.[14]

It was emphasized that a three-step rocket with a take-off weight of only 16 tons and an initial thrust of 30 tons, could project a small rocket into a temporary orbit round the Earth (Fig. 2, Table I). This, the "absolute minimum vehicle" of four examples considered, would have the primary object of placing a body in a closed orbit, without payload, as a first approximation for the purpose of checking the orbital path by means of ground tracking. As the final step of this vehicle would have particularly small dimensions (length 10 ft. × diameter 19 in.), it was suggested that a metalized paper "balloon" might be incorporated as a radar reflector which could be ejected from the rocket and blown up in space. From observation of the behaviour of the "balloon", the density of the air in the outer atmosphere could be determined. As a further development, it was suggested that a small radio-beacon might be embodied in the final step for position-finding, together with an instrument for measuring a single quantity (e.g., cosmic radiation), the data being incorporated in the return signal. An allowance of 10 lb. was made for this equipment.

TABLE I

The G.K.D. Minimum Satellite Vehicle, Proposed in 1951 in a B.I.S. Paper (see also Fig. 2)

	1st Step	2nd Step	3rd Step
Payload (lb.)	6,350	463	0–10
Control (lb.)	—	220	55
Structure (lb.)	2,205	772	66
Pumps and motors (lb.) ..	3,814	661	33
Propellant (lb.)	25,174	4,234	309
All-up (lb.)	37,044	6,350	463
Thrust (lb.)	74,088	12,700	463
Firing time (sec.)	103	103	206
Acceleration	6 *g*	6 *g*	3 *g*
Length (ft.)	51·1	27·2	9·8
Diameter (ft.)	6·2	3·4	1·64
No. of motors	1	1	1

In the same paper, consideration was given to the use of integral propellant tanks and the elimination of structural weight generally (e.g., fins) to bring about useful improvements in the mass ratio. Pivoting motors were suggested as a means of stabilizing the ascent path

(see p. 24).

The other British contribution was a paper by D. F. Lawden,[15] whose extensive mathematical treatment of orbital problems has, for some years, been a major contribution to the field, under the auspices of the British Interplanetary Society.

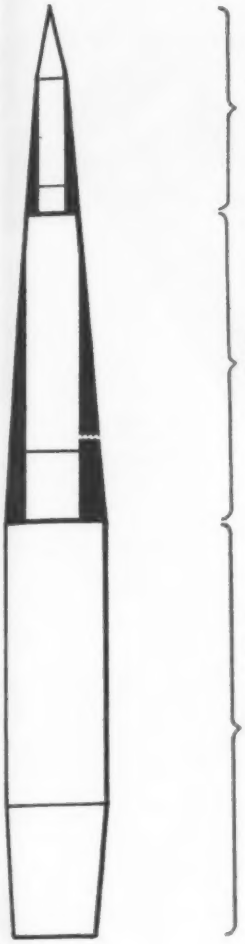


FIG. 2. In a paper, "Minimum Satellite Vehicles," presented at the Second International Congress on Astronautics, in London, in 1951, the author (in collaboration with Messrs. A. M. Kunesch and A. E. Dixon) laid down the original design specifications for close-orbit artificial satellites of the "minimum" type. Four examples of three-step liquid oxygen hydrazine rockets were considered:

(*a*) without payload, for checking the orbital path and drag studies (see Table I);
(*b*) with 220 lb. payload (research instruments and telemetering transmitter);
(*c*) with 385 lb. payload (including additional control equipment); and
(*d*) with same payload as (*c*) but using expendable-tank construction.

The paper also stressed how, by careful design, useful improvements can be made in the structural factor (e.g., omission of fins; tanks built integral with the rocket structure, making use of pre-tensioning effects). It was emphasized that a properly constructed tank, with thin walls and hemispherical ends, can be made to act as an efficient load-carrying structure when full of propellant and highly pressurized. (In the same way, an elongated toy balloon, blown up hard, is quite rigid and will withstand considerable longitudinal compression before bursting.)

Dr. Milton Rosen, Technical Director of Project Vanguard, has acknowledged that some of the background information for the American project originated from this design study.

THE MOUSE PROJECT

The specification for a "minimum" satellite vehicle laid down by Messrs. Gatland, Kunesch and Dixon, in 1951, was adopted by Dr. S. F. Singer for his celebrated MOUSE project,[16] the name of which is derived from the initial letters of the words, Minimum Orbital Unmanned Satellite, Earth. The MOUSE project had fairly modest objectives—the establishment of a rocket, with a minimum payload, in a temporary orbit at a distance of 200 miles. At this altitude, the atmosphere, though highly tenuous, would still be sufficient to exert an influence on the rocket and would eventually cause it to descend. Nevertheless, Singer estimated, the MOUSE would make over 200 circuits of the globe (over a period of 12 days) during which time it would have transmitted to Earth more information of conditions in the upper atmosphere

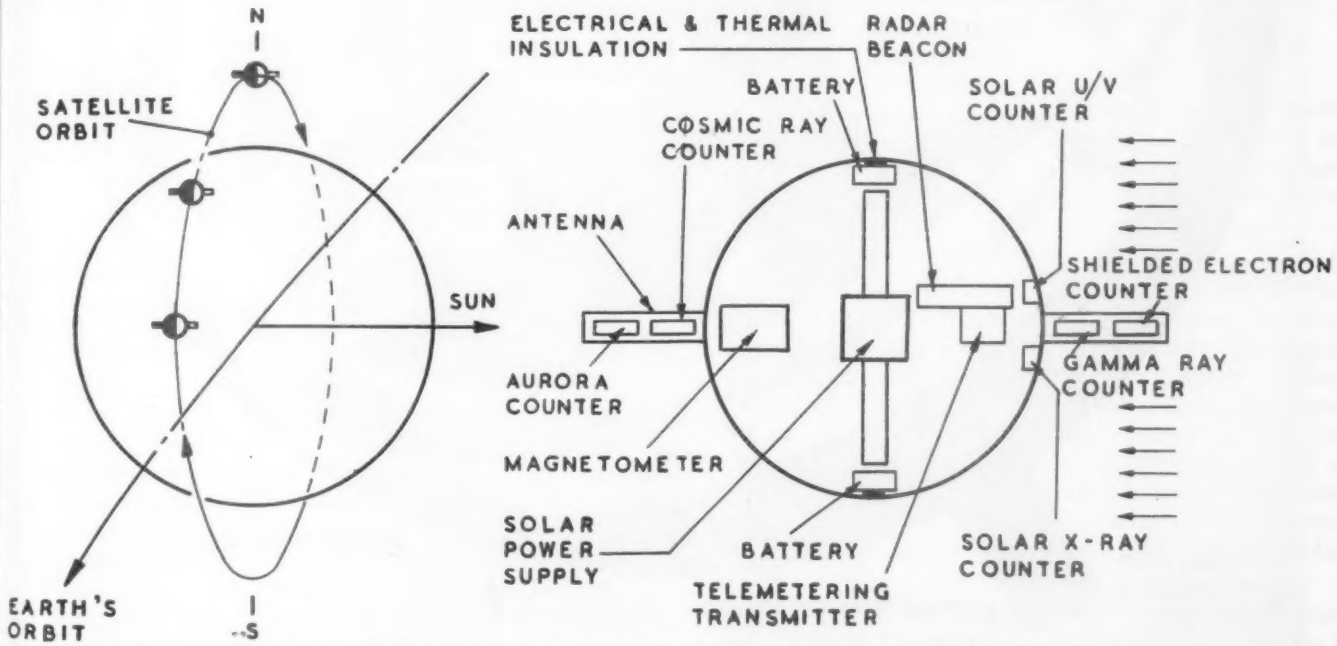


FIG. 3. MOUSE, after a design by Dr. S. F. Singer, University of Maryland. A small spheroid, about 3 ft. diameter, is spin-stabilized about a polar axis which consists of photon or other counting tubes projecting beyond the body. Their cylindrical shape and symmetrical electrode arrangement permit an axial rotation of the satellite while still producing a readable signal. Diagram (*left*) shows satellite on polar orbit, spin stabilized to ensure that solar battery elements are perpetually exposed to sunlight.

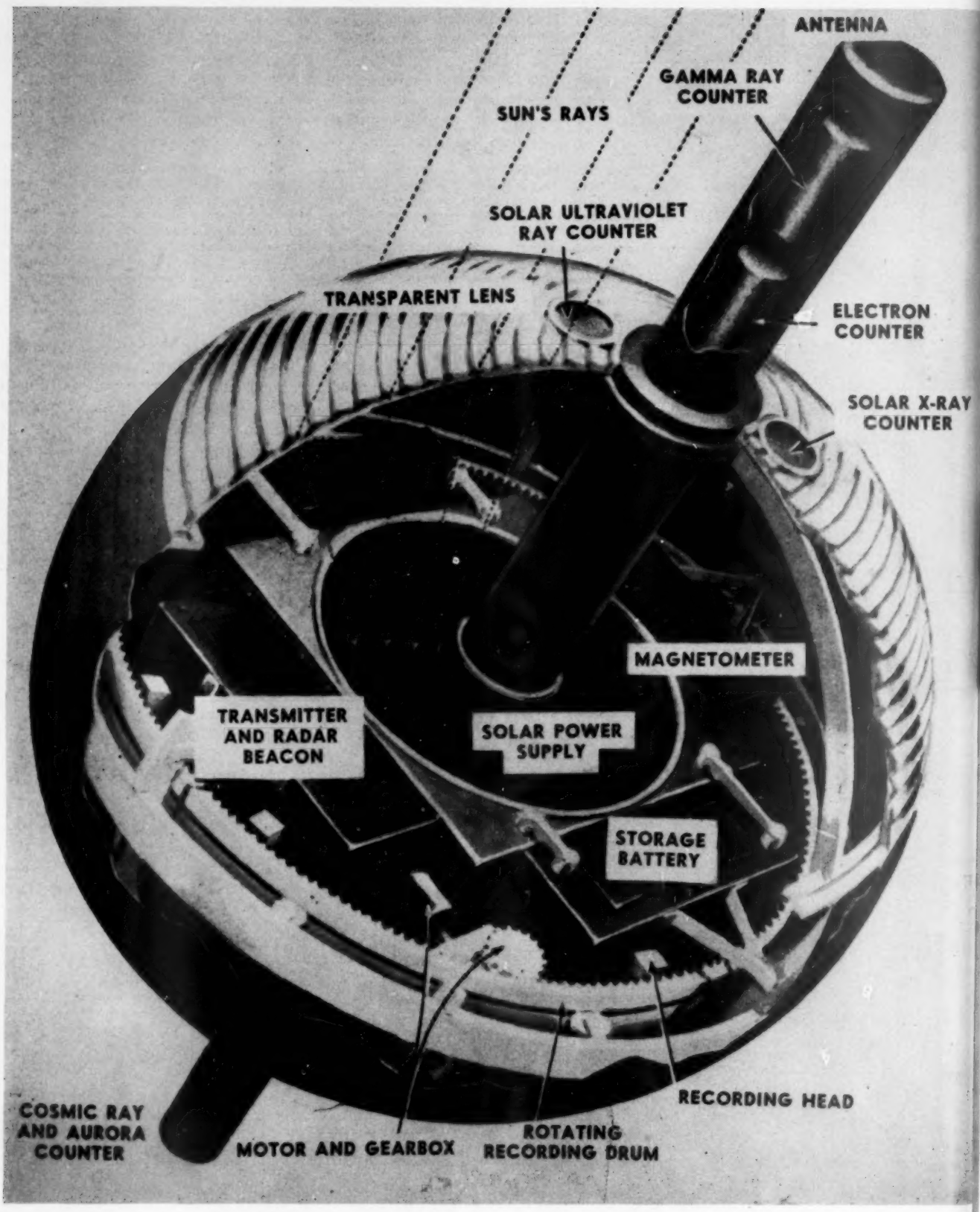


FIG. 4. Small instrumented artificial satellite, proposed by Dr. S. F. Singer (1955)

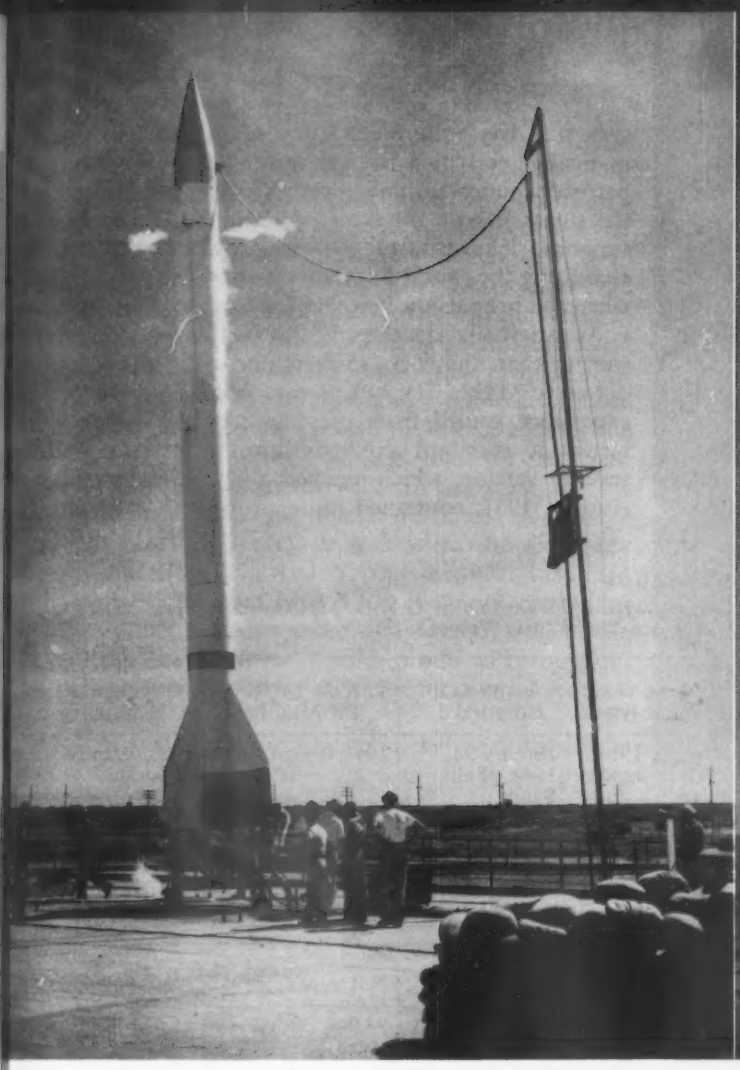


FIG. 5*a*. Viking 7 (1951)

FIG. 5*b*. Viking 9 (1952)

than all the high-altitude research rockets that had hitherto been fired.

Meanwhile, the idea of using a spherical body as a small artificial satellite was taken a stage farther by Dr. I. M. Levitt[17] of Fels Planetarium, Philadelphia, at the Fifth International Congress on Astronautics, in Innsbrück in 1954. Levitt proposed a design for a self-erecting sphere of aluminium-foil which would appear as a first-magnitude star and could be optically tracked. Small instrumental payloads, he said, might be contained within the sphere in the form of a central package.

Subsequently, Dr. Singer himself brought out the design for an instrumented artificial satellite, incorporating a full range of scientific instruments[18]; these included a magnetometer, ultra-violet radiation counters and cosmic radiation counters, linked with a small telemetering transmitter (Fig. 4); at the heart of the satellite was a solar battery. The satellite, designed for operation on a polar orbit (Fig. 3), was intended to be spin-stabilized so that one hemisphere of its shell, fitted with a deflector lens for the solar battery, always faced the Sun. Singer estimated that the complete unit would weigh less than 100 lb.

ROCKET DEVELOPMENT

The development of rocket vehicles capable of establishing small instrumented payloads in orbits round the Earth has sprung largely from American work with high-altitude rockets, in particular the Glenn Martin Viking (Fig. 5).

The specification for Viking was drawn up in 1946 when it was decided that, rather than build the German V-2 in America for upper atmosphere research, it would be more economical to produce an entirely new vehicle designed expressly for the task. Accordingly, a Navy Bureau of Ordnance contract was awarded to the Glenn Martin Aircraft Company in the summer of 1946, for the design and construction of ten sounding rockets (a figure later extended to 14) which would have a potential ceiling of 200 miles. At the same time, Reaction Motors, Inc., received the contract for a 20,000 lb. thrust rocket motor.

The Viking differs from the V-2 in a number of important respects. Probably the most significant of these is the rocket's all-aluminium construction which, together with other weight economies, brought about by careful design, enables a vehicle with less than half the thrust of

the V-2 to reach much higher altitudes. Furthermore, whereas the V-2 rocket obtained stability by means of four carbon vanes disposed in the exhaust stream, the Viking employs a direct system of tilting the entire thrust unit—chamber and nozzle. Both systems work in conjunction with pitch and azimuth gyroscopes, and the effect is the same in that the jet is momentarily deflected—and the thrust consequently offset—to oppose any deviation from course. However, with a pivoting motor it was possible to achieve a weight saving of 275 lb., there was no thrust-loss due to vanes, and the possibility of control vane burn-out was eliminated.

Viking's propulsion unit employs liquid oxygen and alcohol, with a hydrogen peroxide turbo-pump injection system. Any rolling tendency of the rocket is automatically corrected by releasing exhaust from the peroxide pump turbine through valves which increase the steam jets on the sides opposing the roll. In later versions, steam-control jets were provided as a means of stabilizing the rocket during the period of coasting flight, when the propulsion unit was ineffective.

As originally developed, the Viking was 12 inches shorter than the V-2 (45 feet) and only about half its diameter (Table II), but as each rocket benefited from experience gained from previous models, it was by no means a standard configuration. For example, the seventh version, which reached a height of 136 miles in August, 1951, contained more propellant than the first

TABLE II

CHARACTERISTICS OF VARIOUS HIGH-PERFORMANCE ROCKET VEHICLES, WITH COMPARISONS OF G.K.D. MINIMUM SATELLITE VEHICLE (B.I.S. DESIGN STUDY, 1951) AND VANGUARD LAUNCHING VEHICLE

Vehicle	A-4	Viking 1	Viking 7	Viking 11 (enlarged type)	A-4/WAC-Corporal 5	G.K.D. MOUSE PROJECT*	Vanguard†
Launched:	December 17, 1946, White Sands	May 3, 1949, White Sands	August 7, 1951, White Sands	May 24, 1954, White Sands	February 24, 1949, White Sands	1951, design study	1958, Cape Canaveral, Florida
Length ..	46·0 ft.	45·0 ft.	48·6 ft.	42·0 ft.	62 ft. 11 in. (overall)	51·0 ft.	72·0 ft.
Diameter, body (max.) ..	65·0 in.	32·0 in.	32·0 in.	45·0 in.	65·0 in. (A-4)	74·0 in.	45·0 in. (step 1)
Diameter, over fins	11·75 ft.	9·2 ft.	9·2 ft.	13·3 ft.	11·75 ft. (A-4)	Not applicable	Not applicable
Weight, gross..	28,962 lb.	9,650 lb.	10,730 lb.	15,005 lb.	28,718 lb. (total, both steps)	37,044 (total, 3 steps)	22,000 lb. (3-steps p satellite package)
Propellant ..	Liquid oxygen/alcohol	Liquid oxygen/alcohol	Liquid oxygen/alcohol	Liquid oxygen/alcohol	Liquid oxygen/alcohol (A-4), nitric acid/aniline (WAC-Corporal)	Liquid oxygen/hydrazine	Liquid oxygen/alcol gasoline (step 1) Nitric acid/dimeth hydrazine (step 2) Solid-propellant, s burning (step 3)
Weight, propellant	19,170 lb.	6,695 lb.	7,950 lb.	11,600 lb.	19,150 (A-4)	25,174 lb.	N.A.
Weight, payload ..	2,150 lb.	464 lb.	394 lb.	825 lb.	25 lb. (WAC)	0–10 lb. (final step)	21·5 lb. (satellite p age)
Thrust ..	52,000 lb. × 69 sec.	20,450 lb. × 54 sec.	21,080 lb. × 72 sec.	21,400 lb. × 104 sec.	56,000 lb. × 68 sec. (A-4)	74,088 lb. × 103 sec. (first step)	27,000 lb. × 140 (step 1)
Velocity (max.)	5,402 ft./sec.	3,450 ft./sec.	5,865 ft./sec.	6,300 ft./sec.	7,553 ft./sec. (WAC)	26,400 ft./sec. (final step)	26,400 ft./sec. (fin step)
Altitude, all burnt ..	20 miles	N.A.	N.A.	N.A.	20 miles (first stage)	N.A.	130 miles (step 2)
Altitude (max.)	116 miles	50 miles	136 miles	158·4 miles	244 miles	500 miles (orbital height)	300 miles (orbital height)
Remarks ..	Greatest altitude reached by A-4	Premature cut-off of motor	Last Viking with original airframe	Present record for single-stage, unboosted, rockets	First large liquid-propellant step-rocket. Present record altitude	First design study of Minimum Satellite Vehicles (British Interplanetary Society)	U.S. Minimum S lite Project for I national Geophy Year

N.A. = Not available. * See ref. 14. † Provisional design data (Glenn L. Martin Co.).

version and had an overall length of 48 ft. In subsequent rockets, the body diameter was increased to 3 ft. 9 in. to accommodate still more propellant, permitting greater heights to be attained or the carriage of heavier payloads. The greatest altitude was achieved in 1954 by the eleventh rocket of the series which ascended 158 miles, reaching a maximum speed of 4,300 m.p.h.

What were the chief factors leading to this increased performance? One, was to make the propellant a larger proportion of the total weight. The extensive use of aluminium in the construction of Viking enables the take-off weight to include no less than 80 per cent. propellant, which compares with 67 per cent. for the V-2 and 55 per cent. for the smaller Aerobee. A measure of Glenn Martin's success is that when the Company brought out their enlarged Viking in 1952, they had achieved a rocket that held 3,500 lb. more propellant without adding *a single pound of structural weight*, the result of skilful weight economies produced throughout the rocket structure and by the incorporation of reduced area tail fins.[19]

Another method of improving rocket performance is to raise the *specific impulse*—which simply means getting more thrust out of each pound of propellant. The General Electric Company, of New York, announced recently that, during research and development for their "Hermes Project", they had achieved the highest specific impulse ever obtained in a rocket engine, which probably accounts for the use of a G.E.C. motor in the Vanguard first stage (see p. 24).

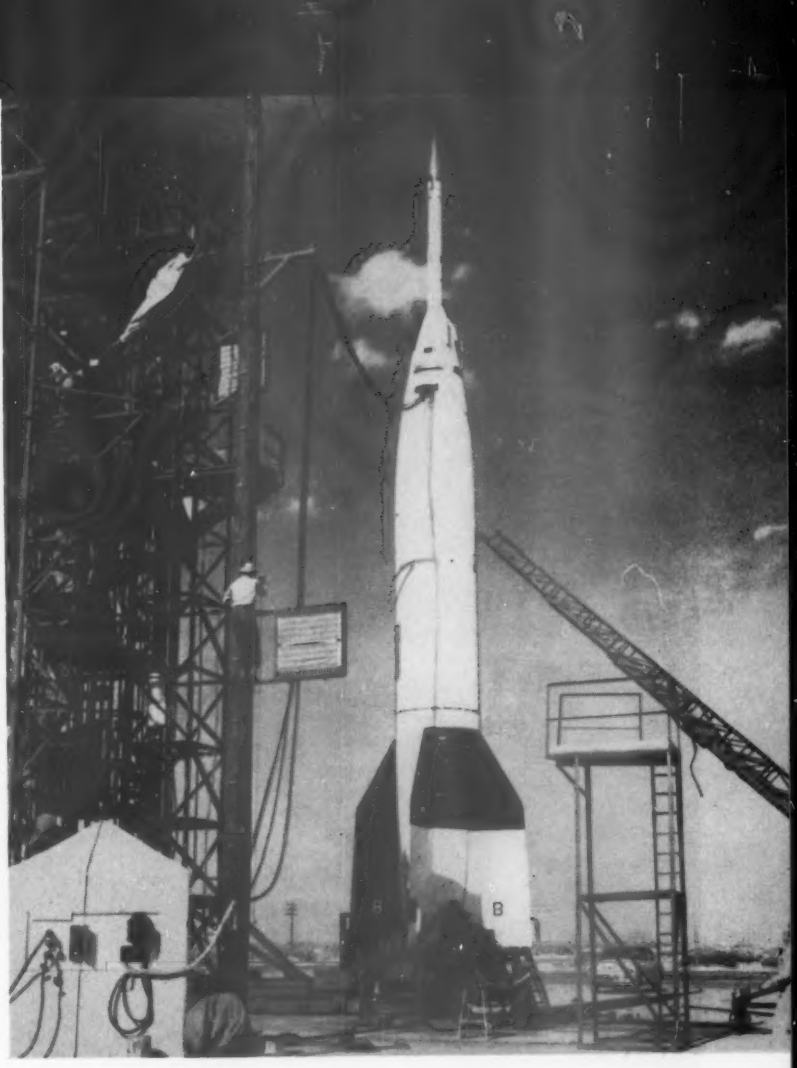


FIG. 6. The first liquid-propellant step-rocket—V-2/WAC-Corporal (1949)

STEP ROCKETS

Despite these and other refinements, there is a limit to the performance that can be obtained from the conventional single-stage rocket. No matter what refinements are made, it will not be possible for the vehicle to exceed by any great margin the speed of its own exhaust (approximately 5,450 m.p.h.). Further gains can only result from step construction. This effectively increases the mass-ratio* of the overall rocket, since each stage is jettisoned immediately its work is done so that no "dead-weight" in the shape of motors, tanks and structure is carried a moment longer than necessary. By this means, three rocket stages each with a mass-ratio of 3·0 will yield the equivalent of a single vehicle with the impossibly high mass ratio of 27·0.

To realize the advantages of the step-rocket (i.e., greater velocity, altitude and range), the U.S. Army Ordnance decided in October, 1946, to start a development programme leading to a two-stage rocket having reasonably good performance. Since the design and construction of a completely new test-vehicle would be very costly and time consuming, it was decided to utilize the existing WAC-Corporal rocket as a second stage to be carried aloft in the nose of a modified V-2 (Fig. 6)

During the period between May, 1948, and July, 1950, eight of these step-rockets were launched, six from the White Sands Proving Ground, New Mexico, and two from the Long-Range Proving Ground, Florida. Rocket No. 5, fired on February 24, 1949, on a near-vertical trajectory climbed 244 miles and attained a speed of 5,150 m.p.h.—the highest altitude and the greatest speed ever to be reached by a man-made object. Rocket No. 7, launched on a low-angle ballistic trajectory, achieved the highest speed ever attained in the Earth's atmosphere. Details of the two latter firings, both low-angle, are still classified.

Despite the fact that most of the other launchings were disappointing, the two really successful rockets (Nos. 5 and 7) achieved significant results. They demonstrated the stability of a two-stage rocket and the satisfactory operation of the separating mechanism. New problems of design, fabrication, handling, launching and in-flight control, were solved. The difficulty of starting a rocket motor at high altitude was successfully overcome (separation occured at 20 miles in the case of rocket No. 5) and progress was made toward overcoming the very severe effects of aerodynamic heating at high supersonic speeds. Two-way communication was achieved with an object 240 miles above the Earth.

* Mass ratio is the ratio between the take-off weight and the dry weight: V-2 = 3·7; Aerobee = 2·2 and Viking = 4·0.

The Inter-Continental Ballistic Missile

Since these pioneer experiments were made, it has become apparent that step-rockets are under development in the United States which will be capable of meeting the performance required for "minimum" satellites. Much interest, for example, surrounds the SM-65 Atlas, a ballistic step-rocket which is expected to have a peak velocity of 15,000 m.p.h. and a maximum range of 5,000 miles.

maximum speed is reached. The rocket's final speed, at the chosen launching angle, will then correspond to the distance of the target. The successful development of rockets of this character will involve the solution of some remarkable problems in the fields of guidance and aerodynamic heating if the missile is to reach its target intact.

The warhead, which may be detached from the final stage at the end of the propulsion period, will probably be

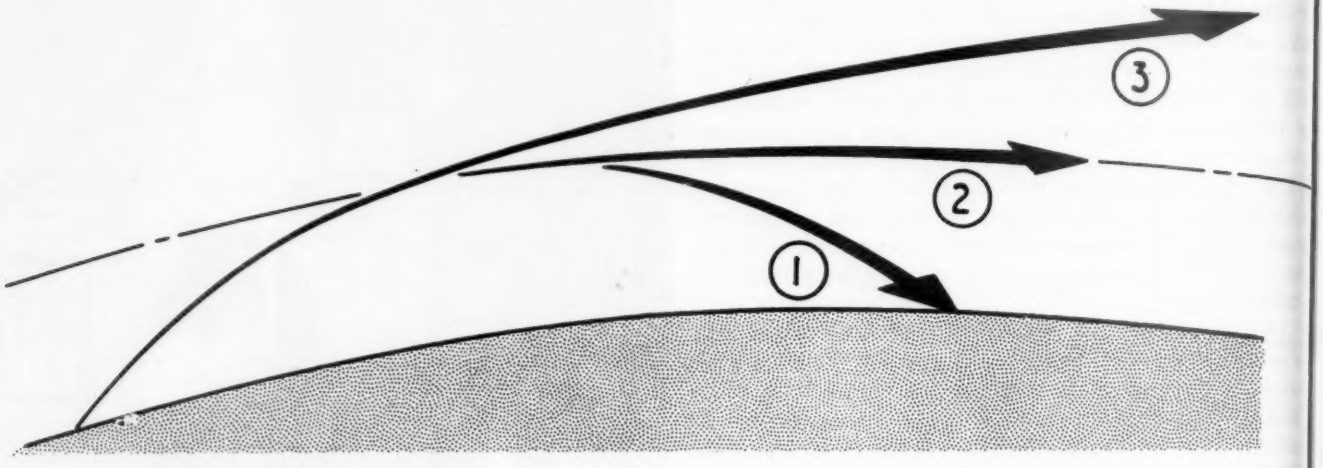


Fig. 7. Three important velocities in space-flight development:—
(1) 15,000 m.p.h.—the intercontinental ballistic missile, range 5,000 miles.
(2) 18,000 m.p.h.—the close-orbit artificial satellite.
(3) 25,000 m.p.h.—for escape missions, pilot-less rocket to the Moon, etc.

It was revealed in February, 1955, by General F. Twining of the U.S. Air Force, that work on the Atlas was in an early development stage. Convair, the principal contractor, is responsible for the overall missile; North American Aviation will supply the rocket engines, and the Arma Division of the American Bosch Corp. the guidance system.

According to American reports, the Atlas is a two-stage rocket with an all-up weight of approximately 100 tons. The configuration is unusual in having a centrally-mounted sustainer chamber of 135,000 lb. thrust, with two chambers of 100,000 lb. thrust mounted on either side of the primary unit. The latter, comprising the first stage, are jettisoned partway through the missile's powered flight, leaving the sustainer section, which carries the warhead, to complete its full engine run of 180 seconds. The maximum velocity of 10,000 to 15,000 m.p.h. is sufficient to drive the missile 800 miles into space before it curves downwards towards its target.

The Atlas will follow a ballistic trajectory like an artillery shell and will be impossible to deflect from course because it will not depend on any form of guidance as it approaches the target. Its accuracy will depend on inbuilt internal controls and radar devices at the launching end; these will ensure that the rocket climbs in the direction of the target at an angle of 25 to 30 degrees and that its motor cuts off immediately the desired

stabilized by means of steam-jets; it will contain a thermonuclear explosive and is expected to have an accuracy radius of 10 to 20 miles which, over a range of 5,000 miles, is small margin for error.

The terrible threat implicit in the alliance of inter-continental ballistic missiles and thermonuclear war-heads, to which the whole world will stand utterly defenceless, is evident for all to see. However, since the very existence of such devastating weapons must surely be the death-blow to war itself, we can at once entertain thoughts of converting some of them to "ploughshares". The scientific possibilities of these giant rockets are extremely encouraging. By adding a further small rocket to the nose of the Atlas, making in effect a three-stage vehicle, the flight path could be extended to such a degree that this final rocket never strikes the ground but remains in space circling the Earth (Fig. 7). To achieve this condition close to the Earth, as we have seen, requires a final velocity of 18,000 m.p.h. A further velocity increment of 7,000 m.p.h. and the rocket will escape from the Earth altogether! When this stage is reached, pilotless "probe rockets" carrying a few pounds and instruments and a telemetering transmitter, will be capable of extending vitally our knowledge of the local universe.

In view of the large amount of development still to be done with inter-continental missiles, neither the

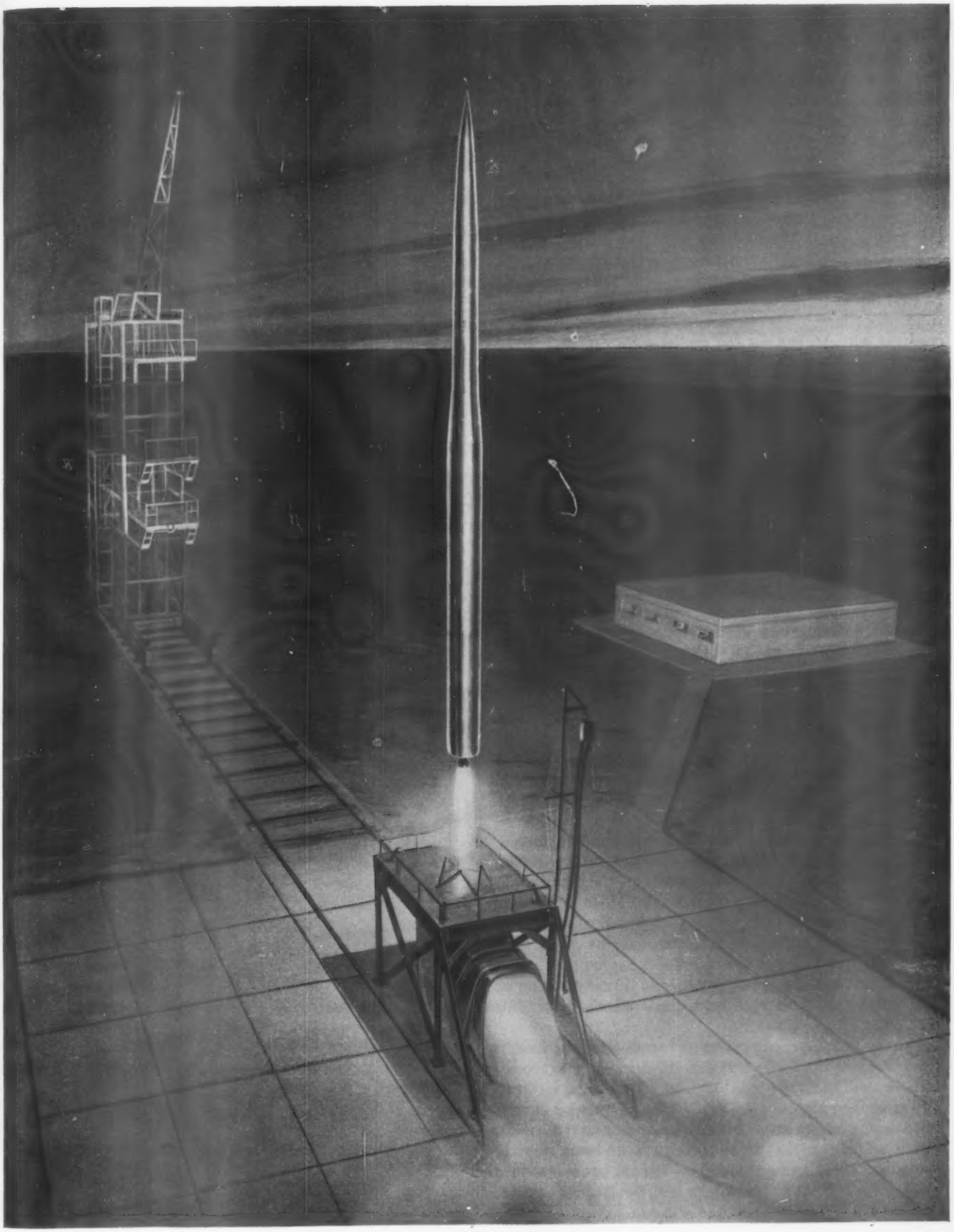


FIG. 8. The Vanguard launching vehicle (1957–1958)

Convair SM-65 Atlas nor a similar weapon to be built by the Glenn Martin Company, will be available for use during the International Geophysical Year. However, the relatively small margin in performance between the I.C.B.M. and a satellite vehicle suggests that great use will be made of it in the future.

Project Vanguard

The U.S. Department of Defense has confirmed that work has begun on a special "minimum" type launching rocket for the artificial satellite to be established during the International Geophysical Year.

The Glenn Martin Company is prime contractor for the Vanguard launching vehicle, a step-rocket consisting of two liquid-propellant stages and a final stage using solid propellant. The General Electric Company has a contract with Martin for the rocket motor to be used in the first stage. A contract for the second stage propulsion system, which consists of a rocket motor and its associated tanks and pressurizing system, has been awarded to the Aerojet-General Corporation, makers of the successful Aerobee and Aerobee-Hi rockets.

The final solid-propellant stage, which has the responsibility for establishing the artificial satellite finally in its orbit, is designed and developed by the Grand Central Rocket Company, of California, and the Allegany Ballistics Laboratory, of Maryland.

In physical appearance, the Vanguard launching vehicle resembles an attenuated rifle bullet and cartridge (Fig. 8), the larger diameter constituting the first step. It will be the first liquid propellant rocket to be controlled entirely without the use of fins.

The first stage resembles the Viking rocket which attained a record altitude (for single-stage rockets) of 158·4 miles in 1954. Although it retains the same diameter of 45 inches, it has been made slightly longer to accommodate more propellant, sufficient to permit a burning time of 140 seconds (compared with the 104 seconds of Viking 11) and a rocket motor that gives a thrust of 27,000 lb. The propellant is a mixture of alcohol, gasoline and silicone oil with liquid oxygen, the two components being fed to the combustion chamber by means of turbine pumps driven by the decomposition products of hydrogen peroxide. The tanks are pressurized with helium to prevent build up of back pressure as propellant is consumed. As in the case of Viking, the rocket motor is gimbal-mounted and under the control of an autopilot, the whole thrust unit can be deflected up to 5 degrees from the rocket's centre-line (Fig. 9).

The second stage, of smaller diameter than the first, is a new rocket; the final stage and the satellite package are enclosed within its jettisonable nose. The rocket motor is also gimbal-mounted. All guidance equipment is carried in this second stage. This includes inertial references which will direct the pivoting motors of both steps to provide pitch and yaw control, movement being obtained by electro-hydraulic actuators. Roll control is provided by small tangentially mounted jets.

The 3-axis gyro-reference system for the rocket complex is designed and built by the Minneapolis-Honeywell Regulator Co., of Minnesota; Vickers Incorporated, of Missouri, are responsible for the autopilot that will control the vehicle's ascent from the launching point. The autopilot will take its instructions electronically from the gyro-reference system, maintaining the vehicle on its planned course by moving the rocket motor so that the thrust pushes the vehicle in the desired direction.

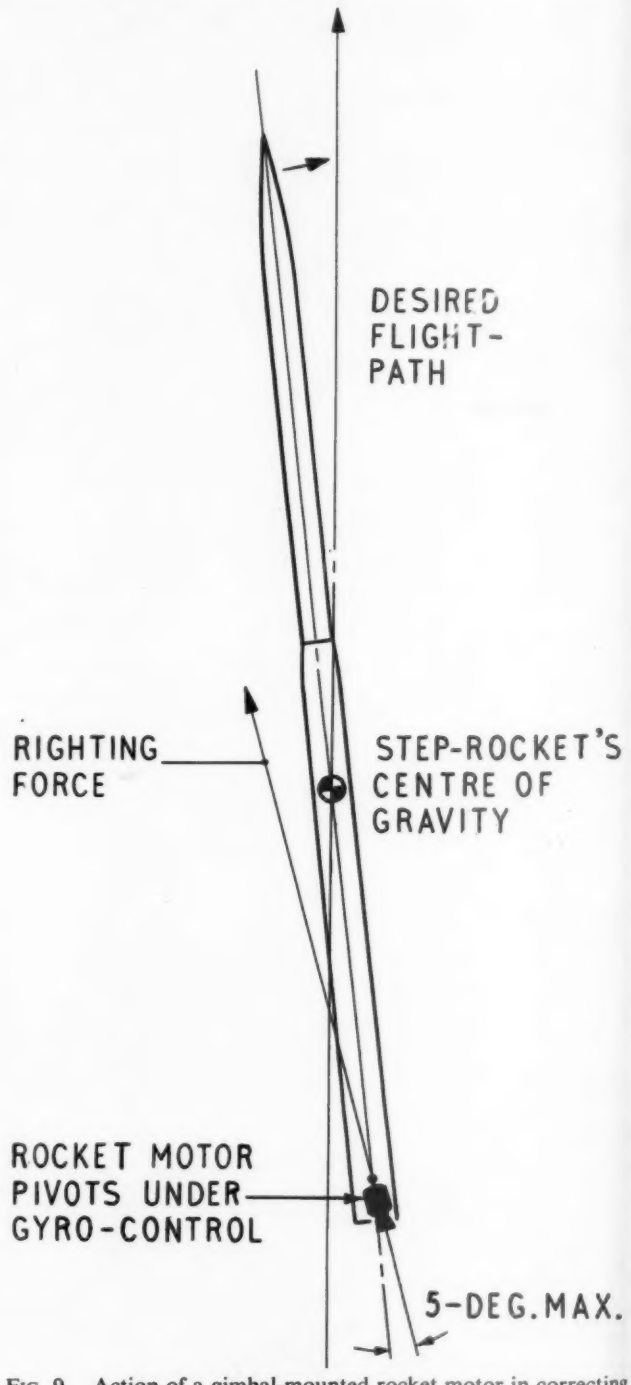


Fig. 9. Action of a gimbal-mounted rocket motor in correcting deviation from flight-path by off-set thrust

Propellant for the second stage is nitric acid and unsymmetrical dimethyl-hydrazine, fed by helium under high pressure, instead of by turbo-pumps as in the case of Step 1. A system of steam-jets will provide complete control after cut-off of the rocket motor.

The structure of the step-rocket, consisting of skin, frames, longitudinal members, and integral propellant tanks, follows the practice of late-series Vikings. A novel feature of the Vanguard rocket, however, is the use of thin-walled integral tanks. These will have little strength when empty, but when full and highly pressurized with helium, they will become "as rigid as auto tyres" and strong enough to serve as the structure of the rocket; there will be no outside skin. These "balloon tanks", making use of pre-tensioning effects, are an entirely new approach to rocket construction and will bring about further useful gains in the structural factor. It is perhaps worth mentioning that some early thoughts on this technique were included in the B.I.S. paper, "Minimum Satellite Vehicles".[14]

FIG. 10. Track of the satellites. Launched from Cape Canaveral, on the east coast of Florida, the instrumented spheres will move round the Earth on a path at 40° to the equator. As the Earth revolves beneath the satellites, they will be observed from intermediate lattitudes (unshaded).

Stage three, the solid-propellant rocket, will comprise a motor tube, expansion nozzle and igniter, the supporting framework for the artificial satellite, and the satellite itself. There will also be provision for releasing the satellite from the motor tube after the assembly is established in the orbit.

LAUNCHING THE SATELLITE

The first launching is expected to be made before the spring of 1958 from the range-head of the United States Long Range Proving Ground at Cape Canaveral, Florida, on a heading between 28 degrees and 35 degrees south to east (Fig. 10). This will provide the best possible orbit for tracking and observation of the satellite at intermediate latitudes, and the rocket will still gain a useful percentage of the Earth's rotational velocity.

The launching sequence is outlined in Fig. 11. After taking off vertically from an elevated launching platform the vehicle will veer to the south-east along its course, the first stage jettisoning at a height of 36 miles. It is expected to fall into the open sea approximately 230

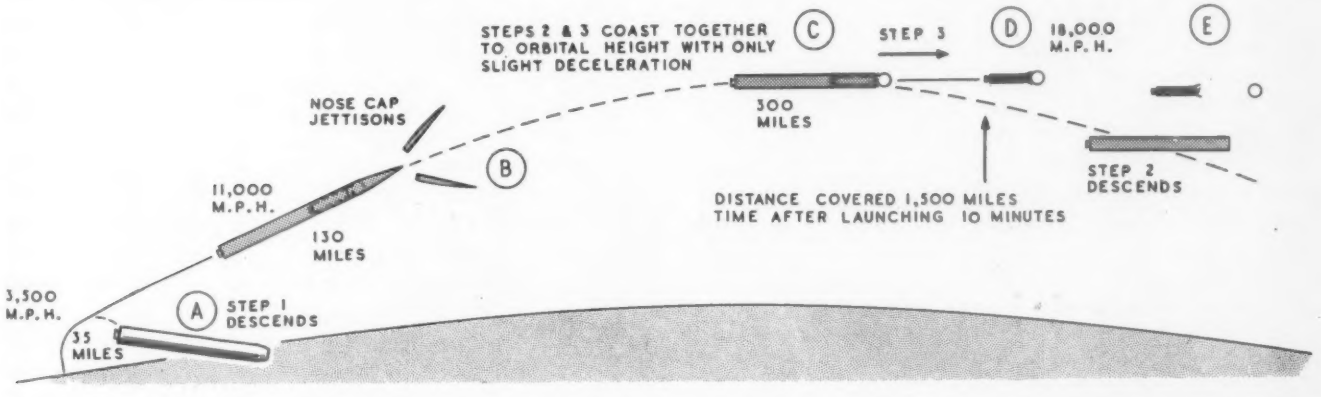


FIG. 11. Ascent of satellite vehicle. After rising vertically from Cape Canaveral, Florida (left), step-rocket turns south-eastwards on ascending path.

(*a*) *Step* 1 jettisons at 3,000 to 4,000 m.p.h. and falls into sea.

(*b*) *Step* 2 accelerates to 11,000 m.p.h. Nose-cap jettisons—steps 2 and 3 coast under momentum to orbital height, 300 miles. Guidance equipment carried in *Step* 2 holds rocket to curved flight path, using pivoting motor and steam control-jets during period of coasting flight.

(*c*) *Step* 3 aligned on path tangential with Earth's surface at peak trajectory by *Step* 2 accelerates to orbital velocity. Final step, comprising long-burning solid-propellant rocket and the satellite package, is spin-stabilized. Meanwhile, empty carcase of Step 2 descends into Atlantic Ocean.

(*d*) *Step* 3 expended at 18,000 m.p.h. (orbital velocity at 300 miles).

(*e*) *Satellite package* separates from *Step* 3. Radio signal from ground station sets telemetering transmitter in operation. *Step* 3 having the same speed as the satellite package, will not immediately fall back to Earth but will remain on similar path to satellite. Both eventually will vaporize due to aerodynamic heating as air drag causes them to spiral deeper into the Earth's atmosphere.

miles from the launching site. The angle of ascent at the time of separation will be about 45 degrees, and the velocity between 3,000 and 4,000 m.p.h.

Step 2, held to a curved flight-path by its in-built controls, will then accelerate to reach a maximum speed of 11,000 m.p.h. at 140 miles. At this stage, the vehicle having outclimbed the denser part of the atmosphere, the ballistic nose-cone (which protects the satellite package from aerodynamic heating) can be thrown off.

Although its propellant tanks are empty, Step 2 will remain attached to Step 3 and the two stages will coast to orbital height (300 miles) with only slight deceleration. During this critical period of the ascent, directional stability will be achieved by means of the programming device in the second stage, acting through a system of auxiliary jet-controls. In this way, Step 3 will be aligned accurately on a path which is tangential to the Earth's surface at the peak trajectory. An axial spin will be imparted to the third step before separation by means of tangential jets in Step 2, whereupon it will accelerate to orbital velocity—18,000 m.p.h. The firing period is expected to be between 30 and 60 seconds, depending upon the accelerative stress permissible on the instruments and the satellite structure.

This final burst of thrust will stabilize the orbit and a releasing device in the nose of the rocket will then free the satellite package for its rôle as a remote scientific observatory. The instruments and telemetering equipment contained in the satellite will be set in operation by a signal transmitted from the ground.

Since both the artificial satellite and the third stage rocket will possess orbital velocity, neither will immediately fall back to the ground but will continue to swing round the globe, making one complete revolution every 90 to 120 minutes, until friction with the tenuous upper air brakes their speed and causes them to spiral deeper into the Earth's atmosphere. The exact time the body remains orbiting our planet will depend on the air density at the satellite altitude and the eccentricity of the orbit. Only the bare minimum of guidance equipment can be built into a step-rocket of "minimum" proportions and inaccuracies in the launching angle of the third step may cause the orbit to vary between heights of 200 and 1,400 miles. Periods of from one month to three years have been estimated for the first satellites.

No attempt will be made to recover the launching vehicle. Both steps 1 and 2 are designed to fall into the open sea within the precincts of the proving range but Step 3 and the satellite package will vaporize as the result of aerodynamic heating upon descending to a height of about 50 miles.

The Satellite Package

The artificial satellite as originally envisaged was expected to weigh 21·5 lb., but the weight and dimensions may vary according to the nature of the experiments to be carried out. The paper-thin 20-in. shells, weighing 4 lb apiece, will be manufactured from a light-weight alloy consisting of magnesium and small quantities of zinc and aluminium. According to a late report, 22 lb. of instruments will be installed in the shells.

Another report suggests that an alternative type of satellite is under consideration which, like the early British proposal, would take the form of a large inflatable sphere with excellent visibility but containing no instruments.

Studies to be made with the artificial satellites range from radiations that bombard our atmosphere, from the Sun and other astronomical sources, to measurements of ionization in the upper air, the Earth's magnetic field, the density and composition of the upper atmosphere, polar lights, air glow, and micro-meteorites.

One of the most important functions of the first satellites will be to determine air density in the outer atmosphere. This will be achieved by ground tracking techniques by measuring the rate at which the satellite package loses speed and height along its orbital track, and will have importance both in studies of the ionosphere and in the engineering design of neo-space-vehicles. In this latter connection, it was reported recently that North American Aviation have a U.S. Air Force contract for a research aircraft—the X-15—which will carry a man 50 to 100 miles into space.* With a top speed of Mach 10 at 260,000 ft., its development will tax engineering resources to the limit. A measure of the aircraft's performance is that it will be powered by a rocket motor with a thrust equal to that of Viking—20,000 lb. Among many unconventional features, its controls will be more akin to those of a spaceship than an aeroplane, for at high altitudes, steering jets will replace the normal ailerons, elevators and rudder. Another important factor will be the effect of aerodynamic heating on the aircraft structure when the machine re-enters the denser atmosphere. Precise determination of the air density throughout the lower altitude range of the artificial satellite will be a valuable pre-requisite for this and similar research programmes.

This is not the only aspect of the satellite programme that will benefit the development of manned space-vehicles. Some of the most vital investigations will concern cosmic radiation, the high-energy particles that continually bombard the Earth's atmosphere and whose origin is still one of the primary mysteries of modern physics. The great difficulty has always been that the cosmic ray primaries cannot be measured from ground level because the atmosphere either destroys them or changes their energy.

Like the highly penetrating radiation liberated by atomic reactors (e.g., gamma rays), cosmic rays are potentially dangerous to living tissue and a great deal more must be learnt about them before men can venture into space for long periods. With the artificial satellite, it will be possible to measure the fluctuation in the intensity of cosmic radiation above the atmosphere which

* In the true spirit of U.S. inter-Service competition, the U.S. Navy have announced that they too have a similar research aircraft under development.

occurs at times of magnetic and solar activity, using particle counters and telemetering. Also, by making observations at different geomagnetic latitudes, variations resulting from the effect of the Earth's magnetic field can be determined.

The charged cosmic ray primaries, which will be the main object of study, consist of approximately 80 per cent. protons, 18 or 19 per cent. alpha particles, and the remainder heavier nuclei. In attempting to move across the lines of force of the Earth's magnetic field, the rays are deflected and those of too low an energy do not reach the Earth at all. It is this group, in particular, that scientists wish to investigate for they are, potentially, the most dangerous to life.

Another source of great interest is solar radiation and satellite investigations may lead to an improved understanding of the Sun, the ionosphere and the Earth's weather and climate. Variations in the intensity of ultra-violet radiation and solar X-rays will be reported to ground observers by means of photon and proton counters and radio telemetering. One of the great advantages of the artificial satellite for this work lies in its ability to measure these quantities before the radiation is filtered by absorbing layers in the lower atmosphere.

Using magnetometers and telemetering, it will also be possible to study electrical currents flowing in and beyond the ionosphere which may lead to a better understanding of aurora and variations which occur in the Earth's magnetic field. One of the direct benefits of this branch of the research may be improved radio communications.

The density of meteorites and micro-meteorites (interstellar dust) in space will also be of interest to the designers of manned research vehicles. By means of impact detectors and radio telemetering, it should be possible to study sizes and velocities of micro-meteorites, whilst the remote chance of the satellite encountering a meteorite large enough to penetrate the shell can be catered for by pressurizing the container. If the shell is punctured, the gas it contains will register shock-waves and a sudden loss of pressure which could be reported to ground stations over the radio link. These particular studies will assist our understanding of the ionosphere, the zodiacal light, and the dust density of interstellar space.

Other measurements will concern temperature. Instruments embodied in the satellite will report changes of temperature as the sphere moves round the globe, alternating between the sunlit side and the side in shadow. It is believed that solar heating may amount to 300 to 400° F. when the satellite is in full sunlight, whereas when it passes behind the Earth relative to the Sun, its temperature may well drop far below 0° F.

In view of the fact that the satellite will absorb a good deal of heat, the instruments and radio gear it contains will have to be suitably protected. One method of countering the effects would be to colour the outer shell white so that as much heat as possible is re-radiated back into space. Also, rotation of the body would be desirable in order to prevent the wide temperature extremes that would otherwise occur between the sunlit side and the side in shadow. In point of fact, it appears that the final step of the launching vehicle will be spin-stabilized, so that the satellite itself will inherit an axial rotation. Present plans include measurements of temperature both within the satellite and on its outer surface.

There is also great interest in the satellite as a tool for geodetic studies, for with its aid the shape and dimensions of the Earth should be determined with unparalleled accuracy. This can be achieved by means of tracking and triangulation using several ground stations at known distances apart. Even to-day, there is still much uncertainty about the exact relationship of the continents, amounting in the case of America and Europe to several hundreds of feet. The artificial satellite will provide a ready means of determining inter-continental distances with great accuracy and will also permit accurate measurements to be made of the Earth's oblateness. Improvements in navigation and mapping will certainly result from these studies.

Finally, it is possible that the satellite may help to determine the distribution and composition of the Earth's crustal mass. Variations in the Earth's gravitational pull as the satellite swings round our planet will distort the orbit very slightly and again by means of tracking and triangulation, it should be possible to discover how the Earth's crust varies both in depth and density.

Of these experiments, it is reported that the following could be achieved with the first satellite: (*a*) drag measurements; (*b*) ultra-violet *or* cosmic radiation; (*c*) meteorite impacts; (*d*) temperature measurements; (*e*) geodetic measurements, and (*f*) distribution of the Earth's crustal mass. At the time of writing, the following agencies have the responsibility for specific research tasks: Air Force Cambridge Research Centre—presence and sizes of interstellar dust, and extreme ultra-violet radiation; Ballistics Research Laboratory, Aberdeen Proving Ground—electron density above the F-layer region; University of Maryland—meteoric erosion of satellite; Naval Research Laboratory—intensity of solar and cosmic radiation, upper atmosphere heating effects on satellite, and upper atmosphere pressure; and State University of Iowa—composition of primary cosmic radiation.

Tracking

The use of elaborate ground tracking equipment will permit the satellite itself to carry only a small and extremely light radio transmitter. Briefly, this consists of a data input circuit which codes all information picked up by the satellite's instruments, and a modulator which superimposes the coded data on a carrier signal. Received at the ground station, this signal is decoded automatically and interpreted as a series of line graphs.

A system of radio triangulation, called Minitrack, using phase comparison techniques, will establish the satellite's position and orbital path. The lightweight transmitter in the satellite will operate at 108 megacycles,

with an output of 10 to 50 milliwatts. There are two alternative designs, one using subminiature valves and the other transistors. It is said that they will weigh only two and three pounds respectively, including antenna and a battery supply sufficient for several weeks intermittent operation. Minitrack will enable a limited amount of research information to be telemetered to earth, but a more elaborate telemetering system is being devised to handle the bulk of data. Information will be transmitted from the satellite only during brief intervals of approximately 30 seconds as the body approaches an official ground station, the radio gear being triggered by a signal from the ground.

Although optical tracking will play an important part in the research programme, the fact that the satellite will only be visible by natural light shortly before dawn and just after sunset, places a limitation upon its use. On the other hand, radio position-finding techniques have been developed to a high degree of accuracy and can be employed both during night and day. For example, Minitrack is expected to provide sufficiently accurate information for scientists to establish the oblateness of the Earth to an accuracy never before possible. Despite errors caused by ionospheric refraction of the signal, the use of data from a number of stations will, it is claimed, enable the satellite's position to be established to within a fraction of a milliradian. Time, speed and position data obtained from different tracking stations will be fed rapidly into a central electronic computor, which will determine the orbit on the basis of this information, and send the particulars ahead of the satellite to assist its location by other sighting stations along the route.

It is perhaps unnecessary to add that a large number of satellites moving on different orbits will be required to obtain comprehensive measurements in all the fields of investigation surveyed here. As a beginning, during the International Geophysical Year, the Americans are planning to launch twelve artificial satellites with the hope that at least five will be successful. In view of the short development time available, this in itself will be no mean achievement.

The following lines, written by Phaedrus 2,000 years ago, are curiously appropriate to the task and the end-product:

> "The mountain groaned in pangs of birth:
> Great expectation filled the earth;
> And lo! a mouse was born."

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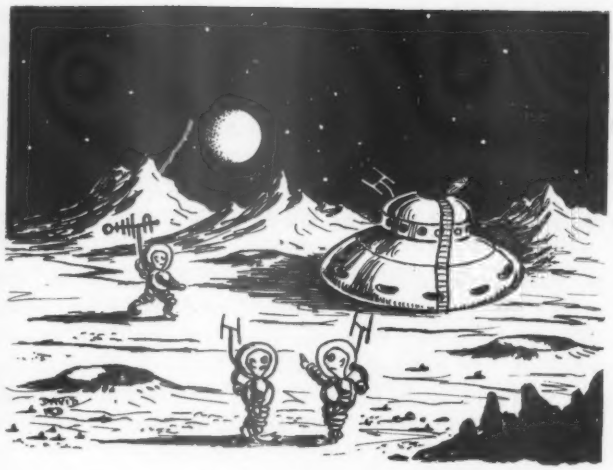
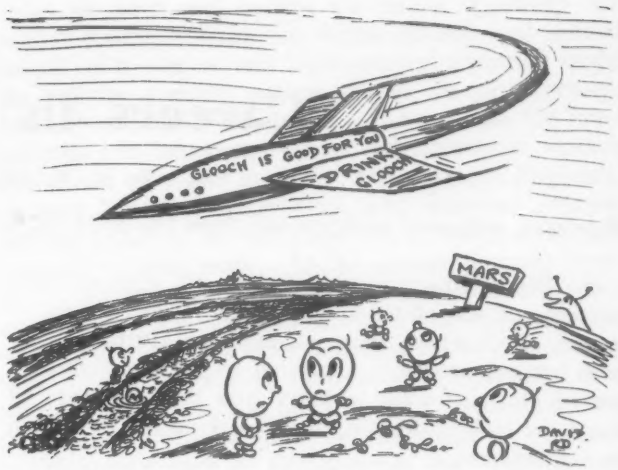
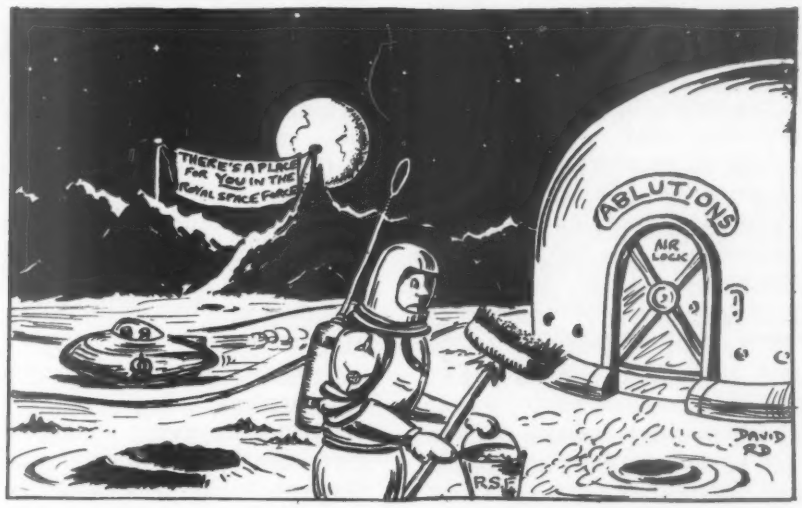


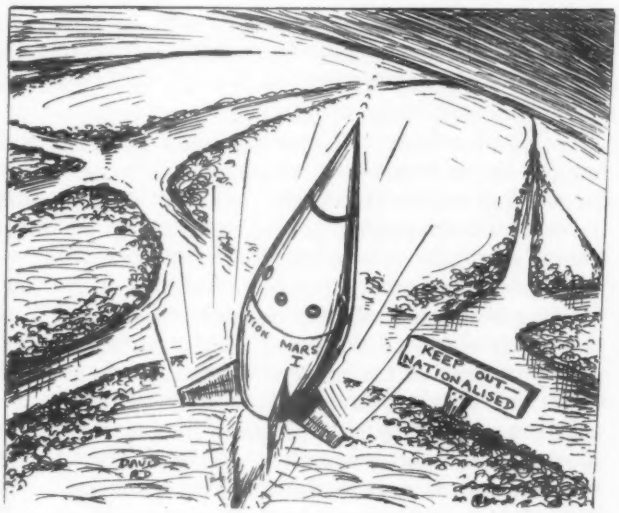
Oh—*He's* gone over to "Commercial"!

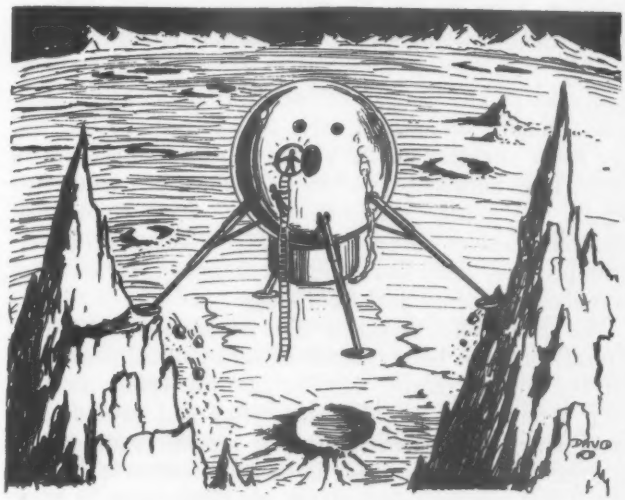


It is doubtful whether any private concern could provide sufficient funds for space travel . . . .



A Glimpse of the Future? *or* A Variation on an Old Theme!





Well—What do we do now?

These are original cartoons drawn by David A. Hardy, a member of the British Interplanetary Society.

Careers in Astronautics

By A. V. CLEAVER, F.R.AE.S.

(*Reprinted, with some modifications, from* THE JOURNAL OF THE BRITISH INTERPLANETARY SOCIETY, Vol. 11, No. 3, 1952.)

The British Interplanetary Society still receives many enquiries on the above subject from various classes of people, all of whom share at least one attribute: they have become intensely interested in the possibility of space-flight, and want to know how they can best set about the task of devoting their working life to help in its achievement.

Most of our enquiries come from youngsters, between the ages of nine and nineteen, who are naturally concerned about their initial choice of a job, and a course of training for it. A surprising additional number, however, come from older individuals who are apparently quite anxious and willing to change their whole mode of life, if only they can obtain the chance to work on the subject that interests them most. The B.I.S. has always been anxious to help its members in any way reasonably possible, and so various Council members once devoted quite a lot of time to answering all enquiries of the above nature individually. It was therefore hoped in this short article to deal with all the relevant points which repeatedly crop up in the letters received from astronautical aspirants of all age-groups and all backgrounds.

In the first place, it should be clearly realized that, at the present time, there can be no such thing as a career specifically and accurately described as "astronautical", for the simple and obvious reason that no one is yet designing and building spaceships. The term "astronautical engineer" cannot yet have the same significance as "aeronautical engineer", therefore, although one day we feel sure it will have. Nor is it yet possible to specialize at any college in rocket engineering, though most modern courses in, say, aero-engine design will pay some attention to the rocket motor. This state of affairs is an entirely logical one, and must be expected to persist for many years to come. Space-flight will eventually *evolve*—after a long and gradual process—from progress made (for quite different purposes) in other branches of science and technology.

The men who designed and constructed the first aircraft had not been trained as aeronautical engineers, for the similar reason that, in the nineteenth century, such a term was meaningless. They had gained their early experience as mechanical or marine engineers, or in some other related field; in this connection it must be noted that personal enthusiasm and determination count for a lot. (Whatever a man's background, if he *really* wants to do something, there is usually a way by which he can accomplish it.) Along similar lines we may expect the designers and constructors of the first spaceships to be drawn from the ranks of such industries as aviation. In particular, they are likely to have worked for years in such fields as the application of rocket propulsion to aircraft and guided missiles, and in the development of such vehicles themselves.

In the second place, it is worth emphasizing once again something which has frequently been stated by this Society—the subject of astronautics, even in its purely scientific aspects, embraces an extremely wide range of subsidiary, but all-important, subjects. So far we have mentioned only the engineers. However, physicists and chemists and metallurgists also occupy key positions in rocket research; so do mathematicians and so—especially in the future—will astronomers. Specialists in electronics are obviously also vital to the progress of rocket flight, in connection with guidance and control problems; when we get the first "ion rockets", they will probably combine with the nuclear physicists to become the most important members of the design and development team working on the "rocket" power plant itself.

Thus a man might enter almost any field of science or technology and still contribute indirectly towards the eventual achievement of space-flight. Within the next generation his contributions are likely to become even direct ones, with more obviously vital connections to the basic theme of rocket flight. The range of subjects involved is really even wider than has so far been indicated; for example, the medical man, beginning by specializing in aviation medicine, will have a great deal to do with the achievement of the first flights out into space.

Let us return from these generalizations to the problems of the mid-twentieth century boy who wants to be "something to do with rockets"—eventually, "something to do with spaceships". Well, obviously he should specialize at school in scientific and mathematical subjects, and pursue such practical hobbies as he can—building model aircraft or radio sets or telescopes, and so on. It is as well, however, that he should not completely neglect other things! Quite apart from the important consideration that the narrow specialist is usually a rather dull fellow, modern languages are useful (because all rocket research is not, and never will be, done entirely in the English-speaking countries). Also any scientist or engineer must be capable of writing a clear report in good, simple English (or whatever else his native tongue may be).

Having specialized in technical subjects at school, our hypothetical youth should then set about entering one of the recognized existing branches of science or technology. Headmasters—and even parents!—should be capable of giving advice, in particular cases, on this sort of thing; they will know, or can find out, about such matters as available scholarship or apprentice training schemes in particular districts.

The remarks which follow are obviously biassed towards British conditions. However, an intelligent reading of them should indicate an interpretation applicable to conditions elsewhere. For example, in the United States, fewer industrial firms seem to run carefully-organized schemes of engineering apprenticeship, or technical training of any sort. It is also probably true that there is less evidence there of the so-called "Welfare State", with relatively easy opportunities of University education through scholarships offered by the State or by local government authorities. However, and on the other hand, most classes of society in the U.S.A. enjoy a much higher income; because of this, and because of the commonly-accepted practice of "working one's way through college", it is usually at least as easy for a young American to become well-qualified in science or engineering as it is for his British counterpart.

For a career in pure science—physics, chemistry or mathematics—at least three years at a University, leading to a recognized degree, is desirable after leaving school. In engineering, two broad avenues are available as alternatives. Either the student may enter a University straight from school, and take an engineering degree, gaining practical experience in short courses at factories during vacations, and (preferably) concluding with one or two years' practical apprenticeship at an engineering works after leaving college. (It is very important that any young engineer, apart from his academic or theoretical qualifications, should also gain some practical workshop experience—at least enough to enable him to see the factory point of view.) Alternatively, he may go straight from school into a recognized apprenticeship scheme with some industrial firm. In the latter case, he will obtain his theoretical training from part-time day and evening courses which lead either to an external University degree, or the award of a Higher National Certificate in engineering, or to the passing of the examinations of one of the professional institutions (e.g., the Institution of Mechanical Engineers, or the Royal Aeronautical Society). Such a course usually lasts five years. Another compromise solution sometimes adopted (especially in Scotland) is the "sandwich scheme", in which the apprentice-student does one year in the works, one year at college, and so on.

In England, various schemes of financial grants, to aid poorer students with University or apprenticeship training, are available. Most big engineering firms operate well-organized apprenticeship schemes, with time off for study at courses run in association with local technical colleges, and with pay for their apprentices during training.

As we have said earlier, the future spaceship will evolve gradually from the rocket aircraft and guided missile of to-day, so our "astronautical aspirant" might do well to consider aeronautics as the path through which he attains his ambition. If he studies the news columns and "situations vacant" advertisements in such periodicals as *Flight* and *The Aeroplane* (in England), or *Aero Digest*, *Aviation Week*, and *American Aviation* (in the U.S.A.), he will soon know which firms are engaged on such work. At the present time the prospects for employment in these fields are, of course, very good; any young man who has done well on a course of training of any of the types described above should have little difficulty in securing a job on some aspect of rocket work. Apart from the firms involved, there is course the British Scientific Civil Service, with its research establishments such as Farnborough and Westcott—at the R.A.E., Farnborough, an apprenticeship scheme is run at the establishment itself. If the youngster in question has specialized in pure science rather than engineering, he may find more opportunities at an official establishment than in industry, but a choice is still likely to be open to him. It takes all sorts to make a world—not least a world in which new technical devices are being created!

Some cautious parents may question whether all the above opportunities do not rest rather precariously on the present troubled world situation. In some measure they do; most of the rocket research now going on would be, at least, drastically curtailed if a real peace suddenly broke out. It seems most unlikely, however, that it would be completely stopped. Even before we see "Earth satellite vehicles" in demand as television relay stations, there are *some* peaceful uses for rockets—as high altitude research vehicles and for the assisted take-off of civil aircraft, for example. Aviation as a whole would not collapse in a world really at peace, and (in any case) rocket technology is not so very specialized that its experts could not, perhaps temporarily, find work to do in other aeronautical spheres, or even in older branches of engineering and science. It is worth emphasizing that our modern world depends increasingly upon science and technology for the whole of its normal functioning—for its food, clothing, general health and comfort, transport, information, and entertainment. In view of this, there must inevitably be a slow but quite irreversible trend towards an increased status and prosperity for the well-qualified technical man, with a growing demand for his services; the only alternative would be a complete change in the basis of modern society and its standard of values. An equally definite (but indirect) consequence of this expansion in science and technology must be an increased tendency towards specialization: one is no longer an "engineer", but instead a mechanical, electrical, electronic, aeronautical, or even nuclear, engineer. All of these, however, will have some part to play in the achievement of space-flight, as also will many other specialists.

From what has been said it should be apparent that the older man wanting to enter the field of rocketry will

be faced with very different problems, according to his particular background. If he is a technical man, with a good training and experience behind him, then he too (at the present time) should find relatively little difficulty in achieving his desire. One could not offer him better advice than to watch the advertisements in the aeronautical press over a period, and make suitable applications. Or he could write to any of the appropriate firms or official establishments, stating his ambitions and qualifications quite clearly; for example, if he were an electronics specialist, he could write to any of the big radio firms, asking if they could offer him employment on missile guidance projects. If they were not engaged on such work they would say "No": if they were, then they might say "Yes". Most organizations much prefer to employ people who really *want* to do the sort of work on which they are actually engaged.

On the other hand, if the individual concerned is, say, a bank clerk in his thirties, then the position is much more difficult, if not impossible. Without a very serious drop in salary and status, such a drastic change of job (even if the opportunity occurs) can very rarely be negotiated after the early twenties are passed. Imagine the position in reverse—if an engineer or physicist wanted to take up banking! (Curious that one has never heard of such an instance. . . .) There seems to be an impression in some quarters that a change of profession into science or engineering can be negotiated with the same ease as into some form of casual or miscellaneous employment. Such a belief is so far from the truth that it can only be described as ludicrous; one cannot become an engineer, a physicist, or a chemist, any more lightly than one can become a doctor or a lawyer. At least, this is true in any real or literal sense. Of course, there are always a number of "fringe jobs", as it were; a junior clerk in a solicitor's office might, in this sense, equally make a claim to be "a member of the legal profession", but that would not make him a lawyer (or attorney—to our American readers).

To borderline cases of the above kind—to very young men who have realized, perhaps *just* in time, that they should embark on the career they really want—one might suggest that they try to make the change in stages. They might first attempt, for example, to secure *any* sort of technical job, and begin some course of theoretical evening studies at the same time. After a series of such changes, they might finish up with what they want, but such a course should not be adopted lightly, without due regard for all the consequences, or in the mistaken impression that all there is to rocket science and engineering is an interest in its more glamorous aspects. Don't forget the blood, toil, sweat and tears—the years of gaining experience and of studying for examinations.

All of which points to the desirability of choosing the right career for yourself in the first place (younger readers please note), but, to all who choose astronautics as their aim, whoever they may be, the B.I.S. says—"Good luck!"

Tercentenary of the Birth of Edmond Halley

1956 marks the tercentenary of the birth of one of England's greatest astronomers—Edmond Halley, who became the second Astronomer Royal in succession to the Rev. John Flamsteed.

Halley's name will always be associated with the great comet, which last returned to the Sun in 1910 and is due back once more in 1986. Halley did not, of course, discover the comet; he established that it revolves round the Sun, and is thus a true member of the Solar System. Yet this was only one of Halley's many contributions to science. Perhaps his greatest contribution was in helping in the production of Isaac Newton's immortal *Principia*. He also made important observations of the southern stars, suggested what is now known as the "secular acceleration" of the Moon's mean motion, and contributed to astronomy in many other ways.

The Hum and the Bug

By P. E. CLEATOR
Founder of the British Interplanetary Society

1

Introduction to astronautics contained in an address given by Dr. Dionysius Lardner to the British Association in 1838:

Men might as well project a voyage to the Moon as attempt to employ steam navigation across the stormy North Atlantic Ocean.

2

Somewhat rash response of a rival news sheet to the Lord Northcliffe offer, made in 1906, of a prize of £10,000 for the first heavier-than-air flight from London to Manchester:

Our own offer of £10,000,000 *to the flying-machine of any description whatever that flies* 5 *miles from London and back to the point of departure still holds good. . . .*

3

Official reply of the First Lord of the British Admiralty to the Wright Brothers, who by 1907 had constructed an airplane which could travel at 40 miles an hour, and cover a distance of more than 100 miles:

I have consulted my expert advisers with regard to your suggestion as to the employment of aeroplanes, and I regret to have to tell you, after the most careful consideration, that the Admiralty, while thanking you for so kindly bringing your proposals to their notice, are of the opinion that they would not be of any practical use to the Naval Service.

4

Text of a 1934 communication received by P. E. Cleator from the British Under Secretary of State, in answer to a letter expounding the merits of propulsion by rocket, and drawing attention to the ever-growing interest being shown in the device abroad (in Germany, work on a prototype of the stupendous V-2 had already been begun):

We follow with interest any work that is being done in other countries on jet propulsion, but scientific investigation into the possibilities has given no indication that this method can be a serious competitor to the airscrew-engine combination. We do not consider that we should be justified in spending any time or money on it ourselves.

5

From a learned discourse on the impossibilities of interplanetary travel, given by Professor F. R. Moulton in his *Consider the Heavens* (The University of Chicago Press, 1935):

It must be stated that there is not the slightest possibility of such a journey. There is not in sight any source of energy that would be a fair start toward that which would be necessary to get us beyond the gravitative control of the earth. There is no theory that would guide us through interplanetary space to another world even if we could control our departure from the earth; there is no means of carrying the large amount of oxygen, water, and food that would be necessary for such a long journey; and there is no known way of easing our ether ship down on the surface of another world, if we could get there.

6

Approbative sentiments expressed in a review of *Rockets Through Space* in the distinguished scientific journal *Nature* for March 14, 1936:

Mr. Cleator thinks it a pity that the Air Ministry evinced not the slightest interest in his ideas; provided that an equal indifference is shown by other Ministries elsewhere, we all ought to be profoundly thankful.

7

Unsolicited aid to B.I.S. recruitment contained in a letter to the Editor of the highly esteemed psychical publication *Light*, to be seen in its issue for January 7, 1937:

Dr. Helgi Pjeturss holds the view that those we have lost are continuing their lives on some distant planet, quite as physical and corporeal as when they were with us. Also, that they communicate through Mediums. I should like to ask him, if this is the case, why spirits always describe their life as a spiritual one, which we can no more understand than deep sea fish can realise the life of the upper air? If they resided in a material world, they could easily give us a clear and accurate description of it. The accounts they give of the conditions on other planets are no more wonderful than those contained in the Martian novels of Edgar Rice Burroughs. They give no new facts which have afterwards been verified. This convinces me that they have never been to them.

As to his complaint of the lack of public interest in the material Universe, things are not quite as bad as he thinks. I may inform him that there is a real live British Interplanetary Society at Wallasey, Cheshire. . . .

8

The B.I.S. at work, according to the illustrious *Daily Dispatch* for August 16, 1937:

A rocket plane which, it is claimed, will fly from London to New York through the stratosphere in about an hour-and-a-half, is to be tested within the next few days.

9

Faintly derisive note on the coming conquest of space in the eminent *Nature* for November 20, 1937:

It may not be generally known that there is a British Interplanetary Society and an American Rocket Society, the members of which are heralding the dawn of interplanetary travel. . . .

10

Another, sixteen months or so later:

We have received vol. 5, *No.* 1 *of the* Journal of the British Interplanetary Society, *a body "founded for the stimulation of public interest in the possibility of interplanetary travel, the dissemination of knowledge concerning the problems which the epoch-making* (sic) *achievement of an extra-terrestrial voyage involves, and the conducting of practical research in connection with such problems." This number of the* Journal *contains designs for a "space ship" intended to perform a voyage to the moon and back. While we may invite the charge of obstructionism if we dismiss the whole affair as a wild-cat speculation, it is necessary for us to remark that, while the ratio of research results accomplished to speculative theorising is so low, little confidence can be placed in the deliberations of the British Interplanetary Society.*

11

The London *Daily Express* for May 11, 1939, quotes Professor A. M. Low on the sad state of Britain's preparedness for the coming war to end war in the realm of guided missiles:

As the British Interplanetary Society probably knows a great deal more about rockets than the Air Ministry. . . .

12

Illuminating sidelight on the high level discussion which followed the submission of the first report of the Findlater Stewart Committee on German rocket research to the Chiefs of Staff in June, 1943, as since revealed in Terence H. O'Brian's Stationery Office publication *Civil Defence*:

Lord Cherwell, for instance, believed that the long-range rocket story was a deliberate hoax. . . .

13

Editorial answer to a reader's query, embalmed in print in the columns of the distinguished *Daily Mirror* for October 18, 1948:

Our candid opinion is that all talk of going to the Moon, and all talk of signals from the Moon, is sheer balderdash—in fact, just moonshine.

14

The reaction of another eminent London daily to the revelation made by the American Secretary of State, James V. Forrestal, in December of the same year, that plans were afoot for the construction of an Earth Satellite Vehicle:

. . . moonshine schemes for platforms suspended in space, reached in rocket-ships, and despatching atom-headed rocket bombs to any part of the globe. . . .

15

Extract from the renowned Johannesburg *Sunday Times* for July 10, 1949:

All nations have been warned by James T. Mangan, the man who claims he owns all space, not to make any trips to the Moon until "Celestia", his nation, has been recognised by U.N.O.

16

Elegant and immortal utterance by Dr. Richard van der Riet Woolley, F.R.S., the new Astronomer Royal, when asked for his views on space travel, after alighting at London Airport on January 3, 1956:

It's utter bilge. . . .

Postscriptum

Historic announcement to be found in the advertising section of the leading astronautical journal and pioneer interplanetary advocate *Nature*, in its issue for May 5 *anno Domini* 1956:

SPACE TRAVEL

A well-known aircraft company commencing on the first stages of this problem requires qualified engineers with upwards of 20 *years of useful life ahead and eager to join in pioneering this development of the aircraft industry. . . .*

The Colours of Martian "Vegetation"

By A. E. SLATER, M.A., M.R.C.S., L.R.C.P., F.R.MET.S., F.Z.S.

When we look at Mars through a telescope, we can see dark patches on the planet's surface. What are these patches?—and if they are made up of plants, what will the plants be like?

Mars shines with a red light because, as a telescope shows, two-thirds of its area is of a reddish-ochre colour. The remaining third is occupied by darker areas which were at first thought to be seas, and are still named as such, like the non-maritime "seas" on the Moon.

But these darker patches were found to be so changeable in area, tone and colour, that the idea of their being seas has had to be given up, and the best-known alternative theory—that they consist of vegetation—appears to have been first put forward in 1878 by E. Liais,[1] a French astronomer then living at Rio de Janeiro.

The colour changes have long been regarded as the most convincing evidence for vegetation of similar nature to that on the Earth. Not only are the dark areas predominently tinted green or blue-green, like earthly plants, but some of them appear to change at certain seasons to colours of the same wide variety as our own autumn leaves, such as the yellow of birches, the russet brown of hawthorns, the crimson of the virginia creeper and the dark chocolate of dogwood leaves. Other areas keep their colour, like our evergreens, but undergo changes of tone from light to dark. An argument from these facts in favour of vegetation must presumably take the following form:—

If there were no vegetation on Mars, the resemblance of these apparent colour changes to those on the Earth would be a rather improbable coincidence. On the other hand, if they are due to vegetation, such a remarkable correspondence of plant colouring on two such different planets as Mars and the Earth would be an equally improbable coincidence, unless we can find reasons why vegetation should always show such a variety of colours, on whatever planet it grows.

Let us take first the predominating greenish colour. On the Earth, it is mainly due to a coloured pigment, chlorophyll, whose function is to trap the energy of sunlight and use it to build up organic substances, mainly carbohydrates, from the carbon and oxygen in carbon dioxide and the hydrogen in water; the oxygen of the water is given off to the atmosphere during this process.

It has been objected that the atmosphere of Mars contains practically no oxygen, which proves that none is being released by the supposed vegetation. Anyway, it is added, this vegetation would be unable to breathe unless a supply of oxygen was available, since plants, like animals, need to take in oxygen to keep their living processes going. There is a neat way of getting round both these difficulties at once; the astronomer H. N. Russell thought of it in 1935 and H. Strughold, of the Space Medicine Department in the United States, has introduced it independently into his book, *The Green and Red Planet*.[2] Their suggestion is simply that the plants retain within their tissues the oxygen they produce and then use it up again in breathing.

Actually, the oxygen taken in by breathing is used to oxidize precisely the amount of substance whose production caused the oxygen to be released in the first place. Consequently while the plant is growing (i.e., building up tissue faster than it can be oxidized) it gives off more oxygen than it takes in; but the surplus oxygen would be exactly used up again when the plant decays by oxidation.

It follows from Strughold's theory that the oxygen cycle on Mars would have to be hermetically air-tight, and this is hard to believe. Yet, if any oxygen were to leak away, however slowly, plant life would gradually die out from suffocation; moreover, while this was happening, the surface of the planet would become cluttered up with dead vegetation, unable to decay by oxidation and thereby replenish the store of carbon dioxide and water needed to keep the chlorophyll mechanism going—unless, of course, the amount of oxygen leakage into the atmosphere, in spite of being too small to detect from the Earth, is not too dispersed for the plants to be able to recover it in some way.

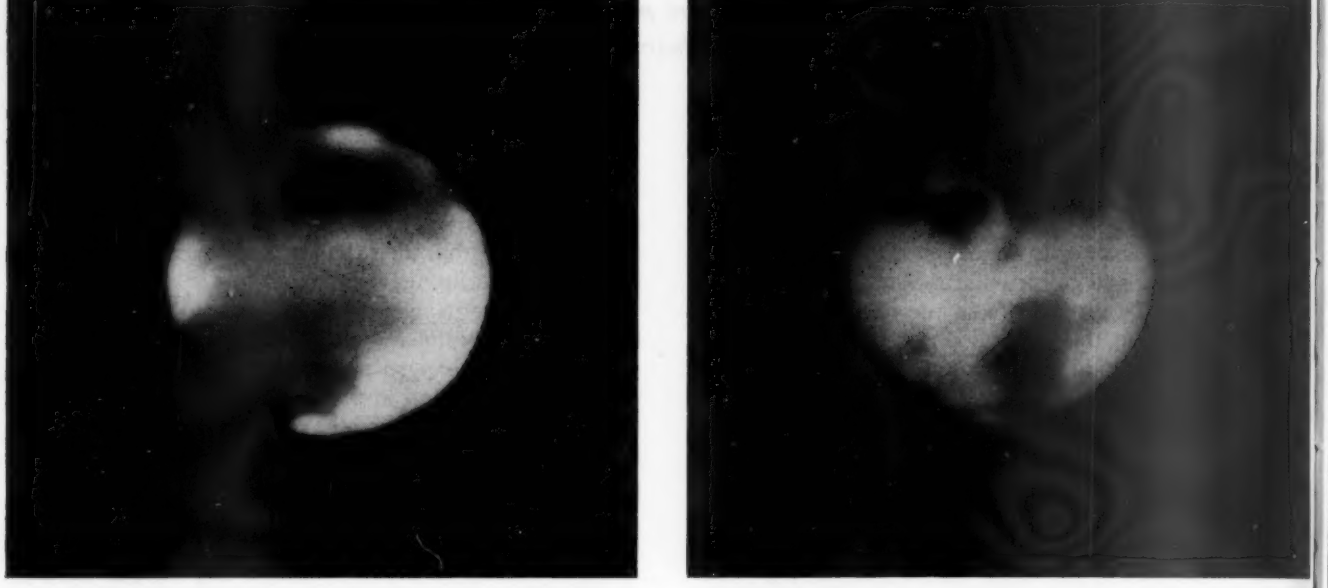
As to the cause of the autumn colours in earthly leaves, scientific information is rather sparse, but the green colour fades in the autumn because no more chlorophyll is produced and any that remains becomes decomposed into colourless materials.[3] As a result, certain yellow pigments are revealed which were formerly masked by the chlorophyll, which nearly always has other pigments associated with it; but there seems no object in these yellow pigments staying on after the chlorophyll has gone, so why should they do so on Mars? Red colours come from oxidation products from the yellow pigments,[3] or from a pigment manufactured from waste sugars and tannin in the leaves; the first source would be plausible on Mars if the plants store oxygen and if there is a reason for the yellow pigment being present, and the second source is not impossible there. Brown is the colour of the leaf skeleton when all life has gone out of it, so its appearance on Mars is rather more plausible than the other colours. But a vast amount of earthly vegetation stays green, especially in the tropics, so all these colour changes are not an

inevitable consequence of the existence of vegetation, even on the Earth.

Unfortunately for any remaining plausibility in the colour analogy, autumn colours on Mars do not arrive in the autumn, in spite of statements to the contrary by

in bright sunlight.[8] So some sort of growth resembling lichens would fit the Martian colour scheme better than green-leaved plants.

It is now time to introduce the spectroscope so that the subject can be pursued further. Energy from the Sun is



Mars photograped in blue light (left) and red light (right) with the 200-inch reflector, Mount Wilson and Palomar Observatories.

Surface details show clearly on the red-light photograph which, as comparison with the chart of Mars shows, was taken when longitude 0° was just left of centre and the southern hemisphere tilted away from the observer. In the blue-light photograph, most of the light is reflected from the atmosphere and the dark areas show through only vaguely.

R. S. Richardson.[4] As an instance, Percival Lowell[5] found in 1894 that the change to brown occurred during mid and late spring in middle southern latitudes, but in 1903 the change came in early winter.[6] Later, E. M. Antoniadi[7] collected as many observations of colour change as he could find in the literature. In the most prominent Martian feature, the Syrtis Major, which lies across the equator, the change to brown came fairly consistently early in the southern summer, when Mars is nearest the Sun and equatorial regions are at their hottest. Antoniadi gives an interesting chart (*La Planète Mars*, p. 20, Fig. 4) showing the colour changes in the southern hemisphere in 1924; in the higher latitudes the change was mostly to brown but in parts to maroon, while in low latitudes carmine and "brown-lilac" were in evidence.

As Strughold[2] has pointed out, the general climate of Mars resembles most nearly that of the tundra regions of the Earth where lichens grow in preference to trees. Lichens show a wide variety of colours, and some of these colours can change; moreover, a change to brown often goes with increased exposure to sunlight, as on Mars. For example, a lichen called *Parmelia saxatalis* is bluish-grey when growing on shaded trees, but deep brown on exposed rocks; and another species, *Xanthoria parientina*, is grey-green in the shade but turns to yellow

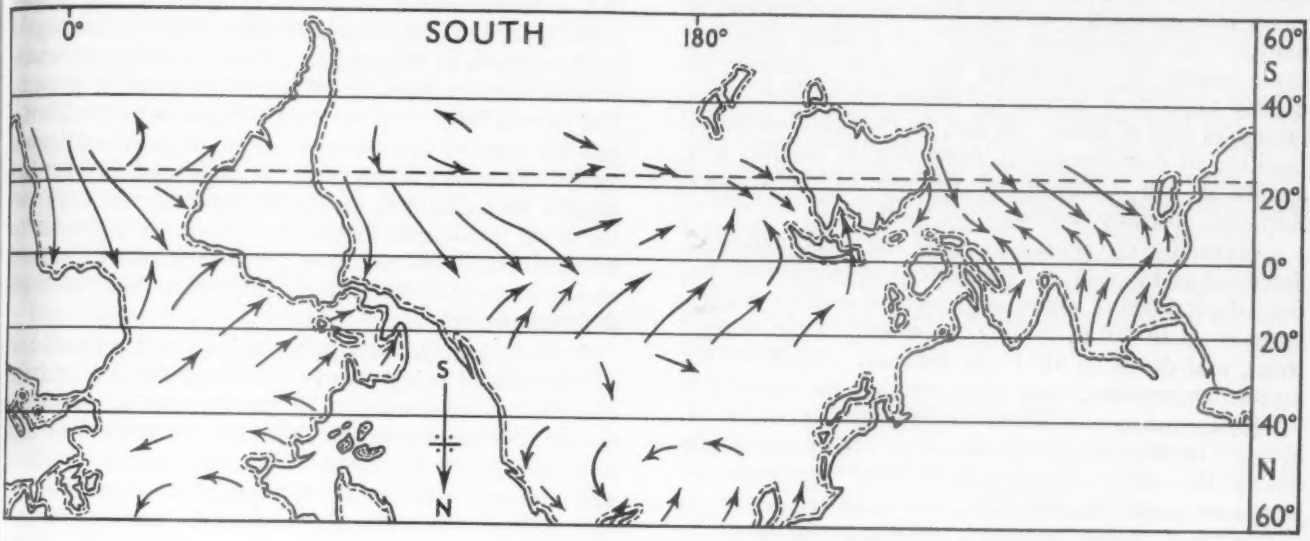
conveyed not only in the various colours which combine to make up its white light, but also in the invisible infra-red waves, which convey quite a large proportion of its total heat. The spectroscope, by spreading out into a "spectrum" the light coming from any particular pigment, shows which colours (i.e., wavelengths) are missing, and it can be assumed that the missing colours belong to those light waves whose energy is being absorbed by the pigment. Thus chlorophyll looks green because the green light is not absorbed, but is reflected back again, to be picked up by the human eye. Chlorophyll also reflects the infra-red light waves, and although we cannot see them, they can be picked up by special photographic plates; this is why most vegetation looks bright in infra-red photographs.

G. de Vaucouleurs pointed out in his first book on Mars[9] that in infra-red photographs of Mars the dark areas still come out dark, not bright as with earthly vegetation. But in his later book[10] he quotes a statement by Lecomte who claims to have proved that this infra-red comes from an internal reflection in the air-filled spaces in the plant, and that it disappears in a vacuum. De Vaucouleurs comments that therefore the infra-red reflection "should be somewhat reduced under the lesser atmospheric pressure on Mars". But surely the reason

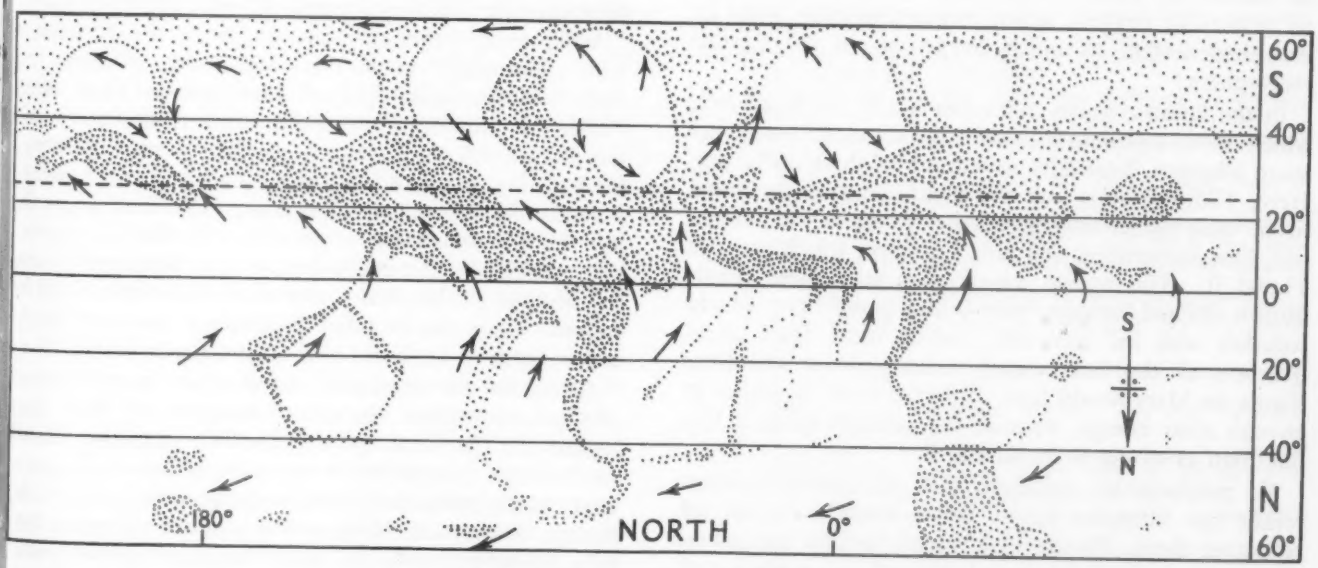
for its disappearance in a vacuum is the collapse of the air spaces; if Martian vegetation contains air spaces, they could not, by definition, be collapsed.

No: a much better explanation can be produced for the absence of infra-red reflection from the Martian dark areas. Fir trees, which are specially suited to cold climates on the Earth, show dark in infra-red photographs, and apparently this is because of resinous material in the leaves which helps to protect them from the cold. This does not mean that fir trees grow on Mars, but it could mean that Martian plants protect themselves from the cold by a similar substance which absorbs the infra-red radiation from the chlorophyll and thus helps to retain some warmth. Tikhov's observations, to be described later, support this argument.

G. P. Kuiper[11] contrasts the spectrum of higher plants, which reflects strongly in a band of wave-lengths in the region where red joins infra-red, with the spectrum of lichens, which give a very small reflection throughout the red and infra-red regions. He points out that the spectrum of the Martian dark areas resembles that of lichens



EARTH. Winds at S. Summer solstice



MARS. Winds at S. Summer solstice, after McLaughlin

To illustrate D. B. McLaughlin's theory that the dark areas on Mars consist, not of vegetation, but of volcanic matter carried by the wind from point sources, his conjectured winds on Mars in the southern Summer (when it is nearest the Sun) are here compared with winds at the same season on the Earth. The broken line shows the latitude at which the noonday sun is overhead at the southern Summer solstice. Note that the "trade winds" converge on this line on Mars, but nearer to the equator on the Earth, because the sea is slow in following seasonal temperature changes. Note also that the dark markings in low Martian latitudes tend to be elongated in the direction of the conjectured "trade winds", with their pointed ends directed up-wind. South is at the top in both charts, in conformity with the usual view of Mars through an astronomical telescope.

in these wave-lengths, but this statement must not be taken as meaning that the Martian spectrum is "characteristic" of lichens; it means no more than saying that the actual spectrum is "not incompatible" with the existence of lichens on Mars.

This brings us to the theories of the Russian astronomer G. A. Tikhov, who had a most interesting article recently in the *Journal of the British Astronomical Association*.[12] Although he pre-judges the issue by declaring in a footnote: "Dialectical materialism teaches that life is a law-governed phenomenon which appears as an iron necessity resulting from the development of matter," he nevertheless makes out a fairly plausible case, mainly by considering the colour spectrum of earthly vegetation in regions where the climate most resembles that of Mars. In fact, in 1947 he founded an Institute of Astrobotany at Alma Ata in Siberia, as a section of the Academy of Sciences in the Kazakh Republic, specially to study such questions.

Incidentally, the climate at Alma Ata could hardly be described as Martian, for the place is in latitude 43° N., only about 3,000 ft. above sea level; the *average* temperature is up to 70° F. in July, according to the *Oxford Atlas*, and drops to 10° F. in January. On Mars the *highest* temperature, soon after noon on the equator, is 77° F., according to radiometric observations by W. H. Sinton[13] in 1954, but it was down to −58° F. at sunrise during the same season, and Kuiper[11] estimates the minimum night temperature to be about −100° C. (−148° F.). Other important differences are that the Martian atmosphere is only about one-twelfth as dense as that of the Earth at sea level, and that it contains no detectable oxygen, which means that there must be less than 0·0015 as much oxygen as in the Earth's atmosphere.[9]

In the Pamirs, nearly 500 miles S.S.W. of Alma Ata, which rise to a peak at 23,000 ft., the climate is somewhat more Martian, especially as the air is abnormally dry. Here, Tikhov points out, the plants tend, as on Mars, to be blue rather than green; he instances the cinquefoil, blue wormwood and blue oxytrope, which grow at 13,000 ft. The reason, he says, is that these plants absorb the red, orange, yellow and green rays, which, together with the infra-red, convey more than three-quarters of the heat energy coming from the Sun. Plants on Mars would have to do the same to gather in enough solar energy, because the sunlight there is less than half as strong as on the Earth.

To reinforce his argument that the Martian plants retain the infra-red rays "for warmth", instead of reflecting them, Tikhov investigated certain species in the colder earthly climates, and states: ". . . it was found that the dispersion of infra-red rays by the Polar juniper is one-third that of the green oats that grow in the central latitudes of the Soviet Union. The higher up in the mountains the Tien-Shen fir grows, the less infra-red rays it disperses. In winter, conifers disperse half the amount of red rays that they do in summer."

As to vegetation being able to withstand extreme cold, Tikhov states that mosses, lichens and algæ have recovered from immersion in liquid air at −190° C. (−310° F.) for several weeks.

Several lines of argument, therefore, point to lichens being the form of vegetation most likely to resemble anything that might be growing on Mars, in spite of the consideration given by Tikhov to other forms; especially as lichens are often found on Earth in places where nothing else will grow.

A lichen is a mixture of two quite different forms of life: a fungus and an alga. The alga is of the single-celled type, and its microscopic cells, which are entangled in the threads of the fungus, contain chlorophyll which enables them to build up substances needed for growth. The fungus helps itself to these substances and evidently gets the best of the bargain. Thus lichens are by no means elementary forms of life; and in spite of what has already been said, this fact must detract somewhat from the many arguments in favour of something similar to lichens being found on Mars, for it seems reasonable to expect the simpler forms to resemble each other most on different planets.

A similar argument could be used against the likelihood of chlorophyll being present on Mars, for it is quite a complicated substance. The structure of its molecule can be seen set out in the February, 1955, issue of *Sky and Telescope*.[14] It consists of some 125 atoms, of which one is magnesium, four are nitrogen, five oxygen, and the rest carbon and hydrogen; the main pattern of their arrangement is a circle of pentagonal rings with a long chain attached at one point. Would not some quite different type of coloured pigment have evolved on Mars?

Well, many other coloured pigments are associated with chlorophyll in earthly vegetation, evidently to collect energy from light of other colours than those which the chlorophyll absorbs. But recent research[15] has shown that they are quite unable to use this energy for building up organic substances; they have to transfer it to the chlorophyll, which is alone capable of doing the job. So it seems fairly reasonable to expect any carbohydrates in Martian vegetation to have been synthesized by chlorophyll, because if any other chemicals could be evolved which can do what chlorophyll does, one might expect them to be found also on the Earth.

As against the vegetation theory, there have been two attempts to explain the colour changes on Mars geologically. The first, by the Swedish physicist Svante Arrhenius,[16] attributed them to the fact that many hygroscopic substances (which have an affinity for water) change colour according to the amount of water they have absorbed; and, like many materials on the Earth, the wetter they get, the darker they become. Kuiper discounts this idea on the ground that there is not enough water in the atmosphere of Mars to account for the colour changes actually seen.

Nevertheless many observers of Mars have established that the dusky areas become distinctly darker at the

very time that the polar ice-cap is melting, and that this darkening begins in the neighbourhood of the ice-cap and spreads gradually into lower latitudes and then across the equator into the opposite hemisphere. It seems practically certain that the darkening is due to moisture, which is probably spread by the atmosphere (though Lowell thought it was conveyed by artificial waterways); and if no geological explanation can be found for it, a biological one seems the only alternative.

This fact of progressive darkening from the poles to the equator is one of the weakest spots in a new geological theory put forward by Dean B. McLaughlin, of the University of Michigan Observatory.[17,18] McLaughlin's case is that the shapes of the principal dark areas tend to repeat themselves round the Martian globe, and that these shapes are what one would expect if the dark matter is scattered by the wind from certain "point sources", assumed to be volcanoes, from which it would spread out in a down-wind direction. The principal winds would correspond to trade winds on the Earth, which blow towards the hottest latitude, though with some deviation due to the Earth's rotation.

The reason why the southern areas darken at about midsummer, McLaughlin suggested at first,[17] is that Mars is nearest the Sun at that time, and therefore the winds are at their strongest; but in his last article[18] he has felt it necessary to allow that moisture could play a part in the darkening. The green colour he attributes to chlorite, one of the products of volcanic ash. The change to brown is explained by him as follows:—"On Earth, a fresh fall of ash, exposed to the air, would yield brownish soil, in part directly without passing through the intermediate green minerals. On Mars the progress toward brown is delayed by lack of oxygen, and the soil may remain long in the greenish stage."

Having now listed the colours seen in the Martian dark areas and their various proposed explanations, it is finally our duty to admit that doubt has been expressed whether these colours are really there. Refracting telescopes, de Vaucouleurs[10] points out, produce a "secondary spectrum" which makes the shadows of craters on the Moon look violet, and some people have attributed the bluish tints on Mars to the same effect, coupled with a greenish tint due to contrast with the bright reddish areas.

An observation bearing on this point was made by the Rev. T. E. R. Phillips[19] in England on October 1, 1941. Looking through his 8-inch refractor, he saw the "seas," especially the Syrtis Major, as "blue-green"; but through his 18-inch reflecting telescope, which would produce no secondary spectrum, he found the same areas "more blue-grey and less green". Yet this is precisely the opposite to what the "secondary spectrum" theory indicates.

As to the "autumn" tints, could they not be due to desert dust from the red-ochre areas being blown by winds on to the blue-green? If so, then the blue-green would have to be periodically renewed, and E. Öpik[20] has used this as an argument in favour of vegetation, though McLaughlin's volcanic theory would explain the renewal equally well. But it is curious that whenever yellow clouds, believed to be dust, have temporarily blotted out a blue-green area, the blue-green is still there when the clouds have cleared away.

In conclusion, any reader who has expected this article to settle the question "Is there life on Mars?" will have to remain disappointed. The writer is not convinced either way; moreover, no-one can decide whether life must necessarily arise on a planet able to support it, until we know how it started on the Earth. This article is no more than an attempt to set out what can be deduced from colours and colour changes.

So, to mitigate the reader's disappointment, if any, let us finish with some light relief from the days when the dark areas were thought to be seas, Here is Arrhenius's explanation of why they change colour: "When these freeze, especially in shallow places, yellowish-red dust from the continent settles on their surface and lends it hues between the original dark green and the light yellowish-red. When the ice subsequently melts this dust sinks in the water, which latter resumes its dark green colour."

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"Have You Read Any Good Books Lately?"

The literature of astronautics

By A. V. CLEAVER

(For convenience, a list of all the books referred to, in order of mention, is given in full at the end of this article, with all essential data there included.)

The modern rocket is a triumph of invention, the first spaceship will be an even greater one—but neither will ever be able to compare in importance with the three greatest of all: language, writing and printing, in that order. Without these, man would sink to a level much closer to the other animals than he now prides himself on occupying, little more able than they to communicate to his contemporaries and his descendants the results of his own experience. It is well to remind ourselves of this, more especially since astronautics (to an even greater extent than any other applied science) will inevitably evolve from the hard work and profound thought of generations of men.

So, what should the earnest student of the subject read, especially if he comes to it freshly enthusiastic but unashamedly ignorant?

He will be least well served if his interest is deeply technical. Of course, any recognized textbooks on engineering, physics, chemistry, dynamics (in particular, celestial mechanics), astronomy, aviation medicine, etc., will contribute to his knowledge. Like any other specialized or applied science, astronautics is built up from the same fundamentals, so if he reads in all these subjects, he should be able to work it all out for himself and start level with the experts. (Who are they? The present writer has sometimes been called one, and it always makes him cringe, blushing and shuffling his feet at the mere thought that anyone should yet pretend to such a distinction. Nevertheless, some experts are undoubtedly more expert than others.)

This article is not about such standard and general works, however. Of those specifically concerned with rocketry and space-flight, the following are particularly worthy of mention.

Sutton's "Rocket Propulsion Elements"[1] is a not-too-advanced and quite excellent all-round survey of rocket engineering. "Ballistics of the Future," by Kooy and Uytenbogaart,[2] is very comprehensive, though often somewhat pedestrian in its mathematics and uninformed in its engineering comment. It is obviously the work of dedicated amateurs, but not amateurish in the usual derogatory sense, for on the whole it is a quite sound and useful effort. Humphries' excellent "Rockets and Guided Missiles"[3] is technical in the descriptive sense but not at all mathematical; the same is true of Gatland's "Development of the Guided Missile."[4] A book on space-flight itself which the layman would call technical, but the highly technical reader only semi-technical, is Clarke's "Interplanetary Flight"[5]; however it is described, it can be highly recommended, not least for its short mathematical appendix. Von Braun's "The Mars Project"[6] is interesting historically, and as presenting the results of a study of a particular interplanetary mission.

Apart from the above, the main sources of information for the technical student must be the periodical literature, notably "Astronautica Acta" (Springer-Verlag, Vienna), the B.I.S. Journal, "Jet Propulsion"(the A.R.S. Journal), "Weltraumfahrt" (the G.f.W. Journal), and the Proceedings of the various I.A.F. Congresses. However, before we leave the subject of technical literature, notice must be taken of several works which retain a considerable scientific interest, although their main importance is now historical, as bright shining beacons of the early pioneering days: Oberth's "Wege zur Raumschiffahrt"[7]; Esnault-Pelterie's "L'Astronautique"[8]; Goddard's "A Method of Reaching Extreme Altitudes," etc.,[9] and his experimental notebooks[10]; Sänger's "Raketenflugtechnik"[11] and his "A Rocket Drive for Long-Range Bombers."[12]

Also, there are several available books dealing not with rockets or space-flight as such, but rather with the current use of rockets for high altitude research: "Rocket Exploration of the Upper Atmosphere,"[13] edited by Boyd and Seaton, Newell's "High Altitude Rocket Research,"[14] and the more popular "200 Miles Up"[15] by Vaeth, and "Frontier to Space"[16] by Burgess.

Any student of space-flight must have some concern with those aspects of astronomy, at least, which are most neglected by modern astronomers: namely, with planetary and lunar astronomy. Probably the most useful books for an amateur with such biassed interests are Whipple's "Earth, Moon and Planets,"[17] Moore's "Guide to the Moon"[18] and "Guide to the Planets,"[19] Watson's "Between the Planets,"[20] and Spencer Jones' "Life on Other Worlds."[21]

Another science associated with astronautics, and in this case a vital one in every sense of the word, is space-medicine. In this field, one might mention the highly technical "Physics and Medicine of the Upper Atmosphere,"[22] and the entirely popular "Man in Space" by Haber.

Turning now to popular books on the subject of interplanetary travel, we find an absolute plethora of these. A few are excellent, many are good, more are indifferent, some are bad—and some are unspeakable.

From a literary and imaginative standpoint, in this writer's estimation the best of all is Clarke's "The Exploration of Space,"[24] which also has the great merit of a thoroughly sound scientific background. The latter quality is shared, to a greater or lesser extent, with a number of other recommended works, notably "Space Travel"[25] (a very solid and slightly more technical work) by Gatland and Kunesch, and Ley's "Rockets, Missiles and Space Travel"[26] (very interesting from, especially, the historical point of view). Leonard's "Flight Into Space"[27] is highly amusing, provocative, full of vivid writing, and with the additional interest of a rather cynical objectivity, being written by a non-enthusiast who is nevertheless not unsympathetic (actually, the science editor of "Time" magazine). A good little popular work on a topical subject is "Earth Satellite,"[28] by Moore. "Rockets Through Space,"[29] the first book by Cleator (the founder of the B.I.S.) was very well-done and exerted a considerable influence in this country; however, it is of course somewhat dated now, first having been published in 1936, although this gives it an interest of its own.

Two books by Martin Caidin, "Rockets Beyond the Earth"[30] and "Worlds in Space,"[31] contain some questionable statements, but are not, on the whole, at all bad, and are notable for some excellent illustrations by Wolff and Schlamp. This brings us to the subject of the picture-books of astronautics, of which there are now a great many, some of them quite outstanding. Of special merit are: "The Conquest of Space"[32] (Bonestell and Ley), "Across the Space Frontier"[33] (von Braun, Ley, Bonestell, etc.), "Man on the Moon"[34] (more von Braun, Ley, Bonestell, etc.), and a British example: "The Exploration of the Moon,"[35] by Smith and Clarke. These works, with their included text, are of course an excellent introduction to astronautics for readers of all ages, but perhaps especially for the young, although those mentioned above are in no sense juvenile books. (All astronauts, of course, remain eternally young in spirit: their most essentially youthful characteristics are faith, hope, and optimism, without which they become lost in the outer darkness of unbelief and scepticism, like some Astronomers-Royal.)

However, a number of books have also appeared, relying on the printed word rather than the illustration but still intended for a younger audience. Thompson's "The Adventure of Space Travel,"[36] Temple's "The True Book about Space Travel,"[37] Moore's "The Boy's Book of Space"[38] and Clarke's "The Young Traveller in Space"[39] are all good examples. Moore's book has more of an astronomical bias than the others: once again, on an all-round basis, Clarke's is probably the best, in this writer's opinion.

Returning to the purely adult audience, two books must be mentioned which have a special human interest, an historical one, and also a lesson regarding the tribulations which pioneers have to face in rocketry, no less than in other fields. (Also, it might be added, regarding the scale of resources necessary if significant results are to be achieved.) These are "V-2—the Story of a Great Weapon"[40] by Gen. Dornberger (the administrative head of the German war-time establishment at Peenemünde) and "The Men Behind the Space Rockets"[41] by Gartmann. Another book which gives some idea of the required scale of effort for a modern rocket project is Rosen's "The Viking Rocket Story."[42]

No works of fiction have yet been mentioned; a great many of the now innumerable ones on the subject of space-flight are, in fact, unmentionable. However, at least three novels by Clarke (B.I.S. Chairman in 1947, and again from 1951 to 1953), and a number of his short stories, are again exceptional in the extent and soundness of their scientific background, more particularly in the plausibility of the technical atmosphere they create. Because of this, an exception is made in quoting the titles of the three novels at any rate: "Prelude to Space,"[43] "The Sands of Mars"[44] and "Islands in the Sky."[45] If science-fiction is well done, it can, of course, be a worthwhile medium of scientific enlightenment, even though its main purpose is to entertain. (And what aspiring astronaut could logically decry the urge to escape?) The great pity is that so much of it is *not* well done, either from the literary or the technical point of view, though of course it is not suggested that Clarke's works are unique in their quality.

I am very conscious of the fact that, in recommending 45 books, I have chosen 18 by prominent English members of the B.I.S. Some explanation would seem to be called for! The obvious one, which must indeed be unanswerable, is that I was invited to write about my personal choice. The selection has therefore been made from the best of those works with which I am most familiar. At least there can be no reasonable doubt that anyone who had read a fair cross-section of the books mentioned here would have gained a very thorough grounding in the literature of astronautics, even though he would still have covered only about half of it. As a final gesture of defiance, I shall mention with approbation the volume of "Collected B.I.S. Papers" to be published later this year by Butterworth and Springer! Anyhow, need we be shy in claiming a leading place for the B.I.S. and its members in publicising the subject of astronautics?

However, enough has been said to indicate that no claim is made that the survey has been exhaustive, or even that it has included *all* the good books on the subject. It has certainly made no serious attempt to cover the foreign language field, for the author suffers from the common and shameful British affliction of speaking only English and American. All the works mentioned were either written in one of these tongues, or are available in translation, or at least are fairly readily obtainable from good booksellers or libraries in the U.K. and U.S.A.

Further details of books mentioned by Mr. Cleaver; particulars are given in the order: title, author, price, publisher (with the original edition usually quoted first).

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2. J. M. J. Kooy and J. W. H. Uytenbogaart, Ballistics of the Future (in English), 59/9, Technical Publishing Co. H. Stam, Holland.
3. J. Humphries, Rockets and Guided Missiles, 30/–, Ernest Benn, U.K.
4. K. W. Gatland, Development of the Guided Missile, 15/–, Iliffe, U.K.
5. A. C. Clarke, Interplanetary Flight, 9/6, Temple Press, U.K., or $2.50, Harper, U.S.A.
6. W. von Braun, The Mars Project, $3.95, University of Illinois Press, U.S.A.
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11. E. Sänger, Raketenflugtechnik, $5.00, re-printed 1945, in German, by EdwardsBros., Ann Arbor, Michigan, U.S.A.
12. E. Sänger and I. Bredt, A Rocket Drive for Long-Range Bombers, $3.95, 1952 re-print of official war-time report (still in German) by Dr. Robert Cornog, 990 Cheltenham Road, Santa Barbara, Calif., U.S.A.
13. Rocket Exploration of the Upper Atmosphere, edited R. L. F. Boyd and M. J. Seaton (proceedings of conference), 75/–, Pergamon Press, U.K.
14. H. E. Newell, High Altitude Rocket Research, $7.50, Academic Press, U.S.A.
15. G. Vaeth, 200 Miles Up, $4.50, Ronald Press, U.S.A.
16. E. Burgess, Frontier to Space, 21/–, Chapman and Hall, U.K.
17. F. L. Whipple, Earth, Moon and Planets, Harvard Books on Astronomy, U.S.A., or 18/6, J. and A. Churchill, U.K.
18. P. Moore, U.K. Guide to the Moon, 16/–, Eyre and Spottiswoode, U.K. [New edition], Collins' Comet Books, 1/6. Norton, U.S.A.
19. P. Moore, Guide to the Planets, 21/–, Eyre and Spottiswoode, U.K.
20. F. G. Watson, Between the Planets, Harvard Books on Astronomy, U.S.A., or 18/6, J. and A. Churchill, U.K.
21. Sir Harold Spencer Jones, Life on Other Worlds, 12/6, English Universities Press, U.K.
22. Physics and Medicine of the Upper Atmosphere, edited by C. S. White and O. O. Benson (proceedings of conference), $10.00, Lovelace Foundation, University of New Mexico Press, U.S.A.
23. H. Haber, Man in Space, $3.75, Bobbs-Merrill, U.S.A., or 30/–, Sidgwick and Jackson, U.K.
24. A. C. Clarke, The Exploration of Space, 15/– or 8/6, Temple Press, U.K., or $3.50, Harper, U.S.A. Also Tauchnitz (International) and Pocket Books (U.S.A.) paperback editions.
25. K. W. Gatland and A. M. Kunesch, Space Travel, 15/–, Wingate, U.K.
26. W. Ley, Rockets, Missiles and Space Travel, $5.95, Viking Press, U.S.A., or 30/–, Chapman and Hall, U.K.
27. J. N. Leonard, Flight Into Space, first published in U.S.A., or 12/6, Sidgwick and Jackson, U.K.
28. P. Moore, Earth Satellite, 15/–, Eyre and Spottiswoode, U.K. Norton, U.S.A.
29. P. E. Cleator, Rockets Through Space, Allen and Unwin, U.K., or Simon and Schuster, U.S.A.
30. M. Caidin, Rockets Beyond the Earth, $4.50, McBride, U.S.A.
31. M. Caidin, Worlds in Space, $5, Henry Holt, U.S.A., or 17/6, Sidgwick and Jackson, U.K.
32. C. Bonestell and W. Ley, The Conquest of Space, $3.95, Viking Press, U.S.A., or 25/–, Sidgwick and Jackson, U.K.
33. Across the Space Frontier, edited by C. Ryan, $3.95, Viking Press, U.S.A., or 21/–, Sidgwick and Jackson, U.K.
34. Man on the Moon (in U.S., Conquest of the Moon), edited by C. Ryan, $4.50, Viking Press, U.S.A., or 25/–, Sidgwick and Jackson, U.K.
35. R. A. Smith and A. C. Clarke, The Exploration of the Moon, 15/–, Frederick Muller, U.K.
36. G. V. E. Thompson, The Adventure of Space Travel, 12/6, Dennis Dobson, U.K.
37. W. F. Temple, The True Book about Space Travel, 6/–, Frederick Muller, U.K.
38. P. Moore, The Boy's Book of Space, 7/6, Burke, U.K.
39. A. C. Clarke, The Young Traveller in Space, 7/6, Phoenix House, U.K., or $2.50, as Going into Space, Harper, U.S.A.
40. W. Dornberger, V-2, 16/–, Hurst and Blackett, U.K., or $5, Viking Press, U.S.A.
41. H. Gartmann, The Men Behind the Space Rockets, 18/–, Weidenfeld and Nicolson, U.K.
42. M. W. Rosen, The Viking Rocket Story, $3.75, Harper, U.S.A., or 21/–, Faber and Faber, U.K.
43. A. C. Clarke, Prelude to Space, 9/6, Sidgwick and Jackson (or as Pan paperback), U.K., or $2.50, Gnome (or as Galaxy and Ballantine paperbacks), U.S.A.
44. A. C. Clarke, The Sands of Mars, 10/6, Sidgwick and Jackson (or as Corgi paperback), U.K., or $2.75, Gnome (or as Pocket Books paperback), U.S.A.
45. A. C. Clarke, Islands in the Sky, 8/6, Sidgwick and Jackson, U.K., or $2.00, Winston, U.S.A.

Reviews

Books on Mars

The Planet Mars. By Gérard de Vaucouleurs (translated by Patrick Moore). Faber and Faber, London, 1950. Price 10s. 6d.

The Mars Project. By Wernher von Braun. University of Illinois Press, 1953. Price $3.95.

The Green and Red Planet: a Physiological Study of the Possibility of Life on Mars. By Hubertus Strughold. Sidgwick and Jackson, London, 1954. Price 7s. 6d.

The Physics of the Planet Mars: An Introduction to Areophysics. By Gérard de Vaucouleurs. Faber and Faber, London, 1954. Price £2 10s.

There Is *Life on Mars.* By The Earl Nelson. Werner Laurie, London, 1955. Price 12s. 6d.

Guide to Mars. By Patrick Moore. Frederick Muller, London, 1956. Price 10s. 6d.

More books have been written on Mars than on any other planet except the Earth. There used to be long intervals between their appearance, but recently, as the above list shows, they have been coming out at an average rate of one per year.

Three of these books are general in scope, though de Vaucouleurs tends to concentrate on controversial problems —in fact, the original French version of *The Planet Mars* was called *Le Problème Martien.* He gets through a general description of the planet in seven pages, saying that the charting of Mars "has scarcely been improved" since 1924, and then settles down to certain special features: the polar caps, bright regions, atmosphere, climate, dark regions, and canals, with a final page-and-a-quarter on "Life on Mars?," the question-mark expressing about all he has to say on the subject.

Here are some points: the weight of evidence is that the dark fringe bordering a shrinking polar cap is real, not an optical illusion; that the yellow clouds are of different character from the desert surface material; that the atmosphere contains less than a thousandth of the oxygen present in that of the Earth; that any water on Mars would boil at temperatures above 40°–50° C. (104°–122° F.) owing to the thin atmosphere; that the canals are not straight, continuous lines, although photos taken by Dr. B. Lyot in 1941 appeared to show that some of them are.

The Physics of the Planet Mars covers all these problems far more thoroughly and in great detail, as well as that of the internal constitution of the planet's globe, regarding which nothing is said, however, about the possibility of volcanoes or of mountain-building. There are extensive quotations from authorities, and a long bibliography, and it is, in spite of the price, an essential book for any serious student of Mars —in fact, there is no denying it is the best book on Mars ever written. It is by no means just a translation of the French version, *Physique de la Planète Mars,* which appeared in 1951, for the author has been at pains to bring it up to date, and continued to add footnotes for this purpose after the main text had gone to press.

Particularly valuable is his list of problems still to be tackled, even with the use of present-day techniques. They include: photographs of different parts of the disc for deducing the optical properties of the atmosphere; reliable data on cloud motions; brightness and colour changes in the dark areas throughout two complete opposition cycles; water vapour amounts deduced from dark spots near polar caps and haze over the cap; amount of equatorial flattening (to deduce internal constitution); dimming of an occulted star by the Martian atmosphere at different heights; laboratory experiments, under simulated Martian conditions, on possible surface materials and lower forms of plant life, together with attempts to induce mutations in these organisms to render them better adapted to Martian conditions.

Regarding clouds, the present reviewer would emphasize that the speed of a cloud is not necessarily that of the air in which it is formed. Often, in a south-west wind blowing across the British Isles, cumulus clouds form over the land but not over the sea; but a Martian astronomer, too far off to distinguish the individual clouds, would simply say that a cloud mass remained stationary over Britain throughout the day.

Patrick Moore's *Guide to Mars,* the latest book to appear, conveys a great amount of up-to-date information and covers every important aspect of the subject in simple and racy language. It includes a chapter on travelling to Mars and an appendix on how to observe it from the Earth. This is the obvious book not only for the beginner but for anyone who has already learned a good deal about Mars and wants to be sure there is nothing he has missed. The author has even netted a piece of exclusive information from Robert Barker, a leading observer of Mars. Once, when Mars was occulted by the Moon, its apparent final disappearance was followed by "a comet-like misty appearance, which also slowly disappeared behind the Moon". It is pointed out that it has too often been assumed that the atmosphere of Mars is no more than 50 miles thick, merely because the radius of the disc in ultra-violet photographs is some 50 miles greater than that of the solid surface as shown in infra-red light; yet the top of the haze and dust layer on the Earth lies below the stratosphere and there are hundreds of miles of atmosphere higher up.

Of the two books about life on Mars, by far the most original is that by Dr. Strughold, who is Head of the Department of Space Medicine in the United States Air Force. He tackles the question as a biologist, discussing the chemical basis and necessary environment of life, especially in its simplest forms, some of which are adapted to extreme conditions which "higher" plants and animals could never tolerate. He shows that the climate of the tundra regions of the Earth resembles most nearly that of Mars.

But the real core of the book is Strughold's demonstration that green plants do not need to live in an atmosphere containing oxygen because they produce oxygen themselves in the course of photosynthesis—the process by which the energy of sunlight is used to build up plant tissues from carbon dioxide and water. All they need do is to retain this oxygen in their tissues and use it again for breathing. Even on the Earth many plants, including lichens, contain a large amount of air space.

Strughold appears to have gone wrong on two points; on page 33 he mistakes the temperatures at the tops of the visible atmospheres of the giant planets for the temperatures of their surfaces (like saying that the Earth could not support life because the cirrus clouds are too cold); and on page 72 he fails to realize that a growing plant necessarily produces more oxygen by photosynthesis than it needs to take in for breathing.

Earl Nelson gives a good summary of the features of Mars and especially of those which come into the argument about the possibility of life, and in this respect it is a most informative book, so that anyone interested in the question will find it well worth reading. But the assertive title is unjustified; he has nothing really new to contribute to the arguments in favour of life. When he says that "wherever in the Universe prevailing conditions do not render it impossible, *life will come into existence,* develop and adapt itself to suit its environment", he forgets that although conditions on the

Earth's continents render life possible, it did not come into existence there, but in the sea. Conditions must first be suitable for life to start; and, for all we know, it may not start even then.

The book has a very fine coloured map of Mars printed on its paper cover, and this should be removed before it deteriorates and stowed safely away, because there is no copy of it inside the book.

Von Braun's *Mars Project* is purely astronautical. It is a detailed description of a possible expedition to Mars, using present-day techniques, which the author frankly admits he worked out as an exercise, with no expectation that the necessary money and labour would ever be forthcoming. It is to be a terrific expedition, using more than five million metric tons of fuel, and carrying 70 men in a whole fleet of spaceships, though only 50 of them actually descend on to Mars and spend 400 days there while their companions go round and round in an orbit awaiting their return. Everything has been worked out on the engineering side, but when the 185-ton "landing boats" glide down on to Mars at 122 m.p.h., they may not find the surface quite as smooth as they expected. The book is now on sale at some bookshops in Britain for £1 10s. The German edition, published in 1952, costs 5 DM, or about 8s. 6d.

A. E. SLATER.

Into Space. By P. E. Cleator. George Allen & Unwin, Ltd. 159 pp. 15s.

Twenty years ago, P. E. Cleator wrote *Rockets Through Space*, one of the very earliest of books on "popular astronautics" to be produced in English. Things have changed greatly since those times, and the new edition of Cleator's *Into Space*, which appeared in its first edition in 1953, is welcome.

The first section of the book is historical, and some of the early work is described; there is also an account of the ridicule and hostility with which the pioneer researchers had to contend. The second section is mainly astronomical; the third is an account of modern developments, and the last takes the reader into the foreseeable future.

The book is most readable. The print and presentation are good, and the illustrations well chosen, though the very poor photograph of the Moon facing page 53 should be replaced in any future edition. There are a few slips: Sir Frank Whittle's company is described as *Pioneer* Jets Ltd. instead of *Power* Jets Ltd., and some of the astronomical data in the appendix need to be brought up to date. These slips do not, however, appreciably mar an enjoyable and informative book.

P. A. C-M.

Rockets and Guided Missiles. By John Humphries, B.SC., A.M.I.MECH.E., A.F.R.AE.S. Ernest Benn Limited, London, 1956. Price 30s.

As Professor A. D. Baxter says in the Forword to this book, "the rocket engine still suffers seriously from a paucity of well-informed literature. For this reason a comprehensive book is a real event." Its publication at such a recent time as to permit its review in this, the first issue of *Spaceflight*, is too a particularly happy occurrence, because this is one of those rare books which the specialist would not be ashamed to show on his bookshelves, nor the layman find so involved as to be unintelligible. The account is entirely factual, with few (if any) embellishments to help the uninitiated. But this is no disadvantage, as the subject matter is well ordered and neatly divided up, so that no topic is laboured so much as to cause the reader to lose his way in a forest of complexity. Despite such commendable brevity, the text must contain about 60,000 words, and thus covers the vast range of technical problems which are usually conveniently overlooked in applying that oft-used epithet "simple" to the rocket. As the author has been engaged on research at the Royal Aircraft Establishment ever since the end of the war (as well of course as being an active B.I.S. member for as long), this material is well-informed and relevant to present-day problems.

About a half of the book is devoted to the rocket engine as such, with chapters on propellants, units, components and testing methods; the accent is on the liquid propellant rocket, though there is an article on the solid rocket. A broad account of the guidance and control of missiles is followed by a description of some particular types. Finally, the many other applications of the rocket, including of course to space travel, are discussed. There are 120 diagrams and photographs in the 200 odd pages, several tables of information, an index and a bibliography. The last-named contains a list of the more important books on this subject, with some very fair and informative annotations on their content.

As to the content of this book, the author has sensibly confined himself to the more practical problems, and avoided the mathematics of the subject, which are in any event well served by Sutton's *Rocket Propulsion Elements*. One can level only one criticism, and this not so much of the author's choice of material but presumably of the choice imposed on him by dictates of secrecy. Thus a lot of the photographs of this book are of American post-war origin, and the missiles described are the German projects of the last war. Excellent and instructive as both the sources of information are, one can but regret that British research is apparently so badly served in this by the responsible authorities.

Be this as it may, the author has made the best display he may of "showing the flag". His publishers have provided a clearly printed and pleasing book. It deserves, and will surely satisfy, a wide market. So wide in fact, that to particularize is to perform little service; but the aspiring student of this subject will certainly find it an indispensable text.

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